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The purpose of this project was to develop and demonstrate a methodology for simultaneously projecting future pollution control costs for all economic activities subject to Federal regulations, which utilized consistent assumptions relating to official Federal projections of the state of the Nation's economy. To assure valid simulation of the impacts of the regulations, the projection model was developed with a scale of sectoral detail that allowed analysis of each industry-specific effluent or emission regulation in effect at the time (nearly 400 sectors). Further, the secondary effects of pollution control expenditures on the economy were simulated. This report demonstrates the utility of the methodology for the intended analyses.

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of a
Comprehensive Assessment

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FOREWORD

The purpose of this project was to develop and demonstrate a methodology for simultaneously projecting future pollution control costs for all economic activities subject to Federal regulations, which utilized consistent assumptions relating to official Federal projections of the state of the Nation's economy. To assure valid simulation of the impacts of the regulations, the projection model was developed with a scale of sectoral detail that allowed analysis of each industry-specific effluent or emission regulation in effect at the time (nearly 400 sectors). Further, the secondary effects of pollution control expenditures on the economy were simulated.

The body of this report demonstrates the utility of the methodology for the intended analyses. However, even though computerized, the system and associated editorial resources were not capable (within reasonable cost and manpower constraints) of producing a comprehensive report that, at any point, was current with all regulations. During the analysis, text drafting, and review periods, a continuous stream of administrative, judicial and legislative actions occurred, which significantly affected the original underlying regulatory and control options which were used to structure the study. In addition, as time progressed, more detailed economic studies of particular industries in many instances led to more precise estimates than there were available during the original data collection phase of the report.

Repeated attempts to update various sections in order to accommodate new data and legislative action resulted in publication postponements, and the flow of regulatory changes has not subsided. Consequently, it became necessary to impose a cutoff date on the incorporation of new data, in order to release the report so that its significant contribution to analytical methodology could be made public.

Therefore, the reader is put on notice that in many instances the cost estimates in this report do not reflect the most current data available. The report makes available to the public the state-of-the-art methodology for producing such estimates and gives an indication of the best cost estimates as they were made at one point in time.

ABSTRACT

The purpose of this project was to develop and demonstrate a methodology for simultaneously projecting future pollution control costs for all economic activities subject to Federal regulations, which utilized consistent assumptions relating to official Federal projections of the state of the Nation's economy. To assure valid simulation of the impacts of the regulations, the projection model was developed with a scale of sectoral detail that allowed analysis of each industry-specific effluent or emission regulation in effect at the time (nearly 400 sectors). Further, the secondary effects of pollution control expenditures on the economy were simulated. This report demonstrates the utility of the methodology for the intended analyses.

UNCERTAINTIES

Whenever a new estimate of national pollution control costs is produced, there is a natural tendency to compare it with related estimates developed by other parties. Such efforts frequently show considerable discrepencies between estimates for ostensibly the same cost categories. Such discrepencies are, in fact, to be expected, due to the vast number of conditions which must be specified to assure that even the category of cost analysis is identical between two different estimates.

Probably the most difficult problem in preparing a comprehensive assessment of this nature, in this particular period of the national environmental programs, is keeping the cost estimates current with respect to the rapidly changing regulation situation. Keeping the economic data base current in the face of the frequent changes in regulations due to legislative, administrative, and judicial decisions is both expensive and time-consuming. Because of resource constraints, the data in this report are consistent with regulations existing in early 1976. Thus, any economic studies of the impact of regulations proposed, promulgated, remanded, or suspended after early 1976 may be at variance with values presented herein, with the exception of automotive emission control costs which have been revised to reflect the Clean Air Act Amendments of 1977. Changes in regulatory emission or effluent requirements frequently result in little or no change in cost estimates, however, since the changes usually relate to expected performance of accepted categories of technology rather than changes in the technology itself.

For each industrial category, assumptions must be made as to what types of technology will be generally applied to achieve the effluent or emission requirements. Estimates must then be made for the variation of capital and operation and maintenance costs with respect to age, size, and location of the many plants within the industrial category. This area is probably the greatest source of disagreement in the field of pollution control cost estimating.

Economic variables are another cause of discrepancies; dollar value deflators, interest rates, equipment lifetimes, wage rates, energy and material costs, economic growth rates, capital availability, and other factors must all be estimated and projected into the future to produce an estimate of pollution control costs over a period of years.

The level of detail of data and calculations may also cause variability in estimates for the same category. Agency resources do not permit exhaustive investigations of all plants in any particular industrial category. Hence, estimates must be made by extrapolating from a small set of data obtained from "typical" facilities. For example, most estimates of industrial control expenditures in this report are based on only two to four plant size categories. For a few important industrial categories where this general estimation procedure was considered insufficient, significant resources were expended on special detailed environmental cost analyses. Results of these studies were sometimes at variance with the more approximate estimates, as discussed in Sections Two and Three.

In addition, the particular purpose of the estimates may not be exactly the same. The estimates in this report represent the expenditures which would probably be incurred if all parties met the regulations on schedule by installing an assumed particular type of equipment. The resulting forecasts are thus unrealistic to the extent that polluting activities fail to meet all requirements on schedule.

The Bureau of Economic Analysis (BEA) of the Department of Commerce conducts periodic surveys of industries to estimate actual pollution control expenditures. These BEA estimates are nearly twice as high as those reported herein in some industrial categories and less than one-fifth these estimates in others. These differences can be attributed to variations in industry category definition, slower or faster equipment installation schedules, different judgements of the amount of industrial expenditures for process modification which can be properly attributed to pollution reduction, and the probable statistical errors in BEA's industrial questionnaire sampling process. Chapter 3 in Section 1 discusses the impact that process modifications can have on pollution reduction and the difficulties involved in apportioning costs between pollution control and production cost accounts.

The closest parallel to the estimates in this report are the estimates for the cost of water pollution control recently prepared by the National Commission on Water Quality. The Commission's estimates involve the same effluent limitations, and many of the same economic assumptions and industrial category definitions. Some of the industrial category cost estimates compare very closely, but there are still categories which differ significantly. These differences are attributed primarily to (1) uncertainties in plant inventories in those industries characterized by large numbers of small plants, (2) differences in professional judgement on what process would most likely be applied to achieve the required effluent quality, (3) differences in industrial growth rates and plant size trends over the decade, and (4) different assumptions about the current status of pollution control in the industries (capital-in-place).

To summarize, variations in estimates of national activities of this level of complexity are to be expected, but detailed examination of the data and calculation procedures can usually explain the reasons for the variations. The general economic assumptions used in this report are explicitly stated in Sections One and Four of the report, and industry descriptions and pollution control process descriptions are described in considerable detail in Sections Two and Three.

TABLE OF CONTENTS

Section — Page

FOREWORD iii
ABSTRACT iv
UNCERTAINTIES v
ACKNOWLEDGEMENTS xvii

I SECTION I--OVERVIEW

Chapter 1--Introduction 1-1
  Problem Overview 1-2
  Assumptions 1-4
    Economic Assumptions 1-4
    Energy Assumptions 1-4
    Air Compliance Assumptions 1-6
    Water Compliance Assumptions 1-7
 Pollution Control Costs: Definitions and Calculation Methods 1-10
  Direct Costs 1-10
    Investment Costs 1-10
    Operation and Maintenance Costs 1-10
    Total Annual Costs 1-11
    Costing Methodology 1-11
    Government Program Expenditure 1-13
      Air Program Costs 1-14
      Water Program Costs 1-14
  Indirect Costs 1-15
 Comprehensive Assessment 1-15
 Alternative Futures 1-16

Chapter 2--The Benefits of Pollution Control Programs 1-19
 Definition of Benefits 1-19
 Physical and Economic Damage Functions 1-21
 Population at Risk 1-26
 Problems of Measurement 1-34

Chapter 3--Pollution Control Cost Reduction Through Process Change 1-37
 Introduction 1-37
 Impact of Process Change Upon the Cost of a Clean Environment 1-37
 Effect of Environmental Standards on the Rate of Process Change 1-38
 Types of Process Change 1-41

Section	Page
Materials Changes	1-41
Process Modifications	1-42
Costing Methodology	1-44
Costing at the Unit Level	1-44
End-of-Pipe Costs	1-46
Allocation of Reference Costs	1-47
Waste Reduction and Revised Abatement Costs	1-48
Economic and Environmental Motivations for Process Change and the Allocation of Cost Effects	1-49
Costing at the Industry Level	1-50
Industry Survey	1-52
Representative Industry Evaluations	1-61
Copper	11-61
Process Changes	1-61
Industry Effects	1-63
Aluminum	1-64
Process Changes	1-64
Industry-Wide Cost Reduciton	1-64
Pulp and Paper Industry	1-65
Process Changes	1-65
Industry-Wide Cost Reduction	1-66
Petroleum Refining	1-66
Process Changes	1-67
Industry-Wide Cost Effects	1-68
Inorganic Chemicals	1-69
Sodium Chloride	1-69
Sodium Carbonate	1-69
Titanium Dioxide	1-70
Chlorine	1-71
Industry-Wide Cost Reduction	1-72
Generalizations	1-73
Range of Pollution Control Savings	1-73
Variations Within Process Change Types	1-76
Materials Changes	1-76
Process Modifications	1-76
Process Substitutions	1-78
Summary	1-79

Section Page

II SECTION II--THE ECONOMICS OF AIR POLLUTION CONTROL

- Chapter 1--Summary 2-1
  - Government Expenditures 2-5
  - Transportation Expenditures 2-7
  - Industrial Expenditures 2-8
  - Comparison of Cost Estimates to the Last Cost of Clean Air Report 2-11

- Chapter 2--Benefits of Controlling Air Pollution 2-16
  - Health Damages 2-16
    - Nature and Effects of Air Pollution Damage to Health 2-16
    - Survey of Source Studies 2-17
  - Aesthetic Damages 2-22
    - Nature and Effects of Air Pollution Damage to Aesthetics 2-22
    - Survey of Source Studies 2-23
  - Vegetation Damages 2-25
    - Nature and Effects of Air Pollution Damage to Vegetation 2-25
    - Survey of Source Studies 2-26
  - Materials Damages 2-30
    - Nature and Effects of Air Pollution Damage to Materials 2-30
    - Survey of Source Studies 2-30
  - More Elusive Damages 2-33

- Chapter 3--The Costs of Controlling Air Pollution 2-40
  - Introduction 2-40
  - Government Expenditures for Air Pollution Control 2-41
    - Program Costs 2-41
    - Federal Program Costs 2-43
    - Expenditures by Other Federal Agencies 2-46
  - Control of Emissions from Stationary Sources 2-46
    - Classifications of Industrial Sources 2-47
    - Costs Related to Required Reduction in Air Emissions 2-51
    - Reductions in Emissions Prior to the Clean Air Act 2-52
    - Reductions in Air Emissions Required by the Clean Air Act 2-52
    - Coal Cleaning Industry 2-62
    - Coal Gasification Industry 2-68
    - Natural Gas Industry 2-73
    - Feed Mills Industry 2-76
    - Kraft Pulp Industry 2-79

Section Page

Neutral Sulfite Semichemical Paper Industry 2-86
Printing Industry 2-89
Chlor-Alkalai Mercury Cells Industry 2-92
Nitric Acid Industry 2-96
Paint Manufacturing Industry 2-99
Phosphate Fertilizer Industry 2-102
Non-Fertilizer Phosphorus Industry 2-107
Sulfuric Acid Industry 2-111
Petrochemicals Industry 2-114
Petroleum Industry 2-120
Ferroalloy Industry 2-130
Iron and Steel Industries 2-133
Iron Foundries Industry 2-143
Steel Foundries Industry 2-145
Primary Aluminum Industry 2-148
Secondary Aluminum Industry 2-152
Primary Copper Industry 2-155
Secondary Brass and Bronze Industry 2-160
Primary Lead Industry 2-163
Secondary Lead Industry 2-166
Primary Zinc Industry 2-169
Secondary Zinc Industry 2-173
Asbestos Industry 2-177
Asphalt Concrete Processing Industry 2-180
Cement Industry 2-184
Lime Industry 2-188
Structural Clay Products Industry 2-191
Surface Coatings Industry 2-194
Steam Electric Power Plants 2-199
Solid Waste Disposal 2-211
  Municipal Incinerators 2-211
  On-Site Incinerators (Commercial and Industrial) 2-212
  Open Burning and Dumps 2-213
Sewage Sludge Industry 2-217
Grain Handling Industry 2-220
Dry Cleaning Industry 2-224
Industrial and Commercial Heating 2-227

Chapter 4--Mobile Source Pollution Control

Mobile Source Emission Controls 2-233
  Introduction 2-233
  Review of Recent Factors Affecting Mobile Sources 2-233
  Light-Duty Vehicle Controls 2-234
    Emission Standards 2-234
    Passenger Cars 2-238
    Fuel Consumption Penalties 2-243
    Light-Duty Trucks 2-246

Section Page

- Fuel Cost Increases 2-246
- Aggregate National Costs for Light-Duty Vehicle Emissions Controls 2-247
- Heavy-Duty Vehicle Controls 2-254
  - Emission Standards 2-254
  - Heavy-Duty Gasoline Engine Controls 2-255
  - Heavy-Duty Diesel Engine Controls 2-258
- Aircraft Emission Controls 2-258
- Discussion of Unregulated Mobile Source Emission 2-261
- Transportation Control Plans 2-266
  - Summary 2-266
  - Introduction 2-267
  - Overall Strategies 2-270
  - Measures that Reduce Emissions Per Vehicle Miles 2-270
    - Inspection and Maintenance Programs 2-270
    - Retrofit Control Programs 2-274
    - Service Station Vapor Controls 2-276
  - Measures that Reduce Total Vehicle Miles Travelled 2-279
    - The Need for VMT Reductions 2-279
    - Strategies to Reduce VMT 2-282
    - Transportation Control Measures to Reduce VMT 2-286
    - Additional VMT Reduction Measures 2-289
    - Costs of Transportation Control Plans 2-289
    - Inspection and Maintenance Programs 2-292
    - Retrofit Programs 2-296
    - Service Station Vapor Controls 2-298
    - Summary Costs 2-299
    - Cost of Implementing Measures tht Reduce VMT 2-303

III SECTION III--THE ECONOMICS OF WATER POLLUTION CONTROL

- Chapter 1--Summary 3-1

- Chapter 2--The Benefits of Controlling Water Pollution 3-11
  - Health Damages 3-13
    - Nature and Effects of Water Pollution Damage to Health 3-13
    - Survey of Source Studies 3-13
  - Outdoor Recreation Damages 3-13
    - Nature and Effects of Water Pollution Damages to Recreation 3-13
    - Survey of Source Studies 3-14
  - Aesthetic and Ecological Damages 3-16

Section **Page**

Nature and Effects of Water Pollution Damages on Aesthetic and Ecological Values 3-16
Survey of Source Studies 3-16
Production Damages 3-17
Nature and Effects of Water Pollution Damage to Production 3-17
Survey fo Source Studies 3-18
Property Value Damages 3-20
Nature and Effects of Water Pollution Damages as Reflected in Property Values 3-20
Survey of Source Studies 3-20

Chapter 3--The Costs of Controlling Water Pollution

Introduction 3-27
Scope 3-27
Assumptions 3-28
Federal Compliance Assumptions 3-28
Wastewater Treatment Systems 3-33
Stages of Treatment 3-37
Nonpoint Source Water Pollution Control 3-38
Government Expenditures for Water Pollution Control 3-39
Program Costs 3-39
Federal Program Costs 3-41
Assistance Programs 3-41
Regulatory Programs 3-42
State Program Costs 3-45
State Role 3-45
Aggregate State Program Expenditures 3-46
Expenditures by Other Federal Agencies 3-46
Municipal Control Costs 3-47
Introduction 3-47
Defining and Measuring Need 3-47
Defining Cost 3-48
Status of Public Sewerage 3-49
Needs Survey Summary 3-54
Categories of Need 3-54
Results of the Survey 3-55
Projected National Survey 3-57
Time Phasing and Annualization of Costs 3-62
Industrial Control Costs 3-63
Introduction 3-63
Methodology 3-63
Cost Concepts 3-63
Modeling an Industry 3-64
Industry Cost Summaries 3-65
Feedlots Industry 3-68
Beet Sugar Industry 3-75
Cane Sugar Refining Industry 3-81

Section Page

Dairy Processing Industry 3-86
Fruits and Vegetables Industry 3-92
Grain Milling Industry 3-98
Meat Processing Industry 3-105
Seafood Processing Industry 3-112
Leather Tanning and Finishing Industry 3-120
Textiles Industry 3-126
Builders Paper and Roofing Felt Industry 3-133
Pulp, Paper, and Paperboard Industry 3-140
Plywood, Hardboard and Wood Preserving Industry 3-150
Inorganic Chemicals Industry 3-156
Fertilizer Chemicals Industry 3-172
Organic Chemicals Industry 3-180
Phosphate Manufacturing Industry 3-191
Plastics and Synthetics Industry 3-199
Petroleum Refining Industry 3-205
Rubber Processing Industry 3-213
Ferroalloy Industry 3-223
Iron and Steel Industry 3-228
Bauxite Refining Industry 3-239
Primary Aluminum Smelting Industry 3-244
Secondary Aluminum Smelting Industry 3-251
Primary Copper Industry 3-254
Primary Lead Industry 3-264
Primary Zinc Industry 3-269
Asbestos Manufacturing Industry 3-274
Cement Industry 3-281
Insulation Fiberglass Industry 3-286
Flat Glass Industry 3-291
Pressed and Blown Glass Industry 3-297
Electroplating 3-303
Steam Electric Power Industry 3-310
Soap and Detergent Industry 3-317

IV SECTION IV--A COMPREHENSIVE ASSESSMENT OF POLLUTION CONTROL: IMPACT MEASUREMENT UNDER ALTERNATIVE FUTURES

Chapter 1--Impact Estimation Using the Strategic Environmental Assessment System (SEAS) 4-2

Chapter 2--Scenario Assumptions 4-4

Chapter 3--Macro-Analysis Results 4-8
  The Reference Scenario 4-10
  Comparison of the Reference and Reference Abatement Scenarios 4-20

Section **Page**

Comparative Analysis for the Low Productivity Scenarios 4-32
Comparative Analysis for the Energy Conservation Scenarios 4-49

Chapter 4--Sectoral Analyses Results 4-66
  Estimating the Reduction in Air Residual Generation 4-66
  Estimating the Reduciton in Water Residual Generation 4-78
  Estimating the Cost of Pollution Control 4-86
  Industry Investment 4-90

Chapter 5-Estimating Pollution Control Costs 4-100
  Comparison of SEAS Investment Estimates for Air Pollution with Estimates of BEA 4-100
  Estimating Significant Environmental Control Costs 4-101
    Estimating Air and Water Costs for Industrial Sectors 4-102
    Estimating Air Costs for Mobil Sources 4-102
    Estimating Water Costs for Municipal Treatment 4-103
    Estimating Air and Water Abatement Costs to Government 4-104
    Estimating Pollution Control Cost Impacts 4-105
      Capital and O&M Impacts 4-106
      Employment Impacts 4-109
      Energy Impacts 4-112
      Ranking of Sectors by Degree of Economic Change 4-113
    The Dynamic Nature of Total Pollution Control Expenditures 4-120

Appendix A THE SEAS SYSTEM A-1

  The Interindustry Economic Forecasting Mode (INFORUM) A-4
  The Sector Disaggregation Model (INSIDE) A-7
  The Abatement Cost and Feedback Model (ABATE) A-8
  The Relative Commodity Price Mode (PRICES) A-12
  The Industrial Environmental Residuals Model (RESGEN) A-13
  The Transportation Models (PTRANS and FTRANS) A-15
  The Energy Use Model (ENERGY) A-16
  The Stocks Reserves and Prices Model (STOCKS) A-16
  The Solid Waste and Recycling Model (SOLRECYC) A-16
  The Summary Report Generators (POSTCOMP, INFRPT, and CLEANSUM) A-17

Appendix B SCENARIO ASSUMPTIONS B-1

Section Page

Reference Scenario B-1
Reference Abatement Scenario B-5
Low Productivity Scenarios B-7
Energy Conservation Scenarios B-8

Appendix C IMPACT OF INCREASED FEDERAL GRANTS FOR MUNICIPAL WASTEWATER TREATMENT C-1

Appendix D ESTIMATING THE COST FOR INDUSTRIES TO CONTROL POLLUTION

Cost Estimation Methodology D-1
Industrial Segments: Model Plants, Unit Costs and Growth D-2

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Section One

OVERVIEW

Chapter 1

This report begins with an overview section which presents a discussion of those issues common to the study of both air and water pollution control. The next two sections present the costs of pollution control for air and water, respectively, together with estimates of the reduction in environmental pollution effected by the controls. The fourth and final section presents an analysis of the economic impacts and tradeoffs associated with these costs. Particular emphasis is placed on illustrating how these impacts and tradeoffs might change under alternative sets of assumptions about future economic activity and energy conservation policies.

Included in the overview (Section One) is a presentation of the basic assumptions and general approach taken in the development of control costs and in the analysis of the consequent impacts of these costs. This is followed by a discussion of the concept of benefits as applied to the economic analysis of pollution control. Finally, the economic advantages of controlling pollution through process changes are presented. Five major industries are used as examples in this analysis: Copper, Aluminum, Pulp and Paper, Petroleum Refining, and Inorganic Chemicals.

Both Sections Two and Three begin with a brief summary followed by a discussion of the estimated types of damages resulting from pollution. In Section Two, the cost of controlling air pollution is presented in terms of government program expenditures, industry and utility control costs, and transportation control costs. Section Three, on the cost of controlling water pollution, also includes a presentation of government program expenditures, followed by municipal and industrial cost estimates.

A comparative analysis approach is taken in Section Four to examine the relative impact of pollution control under alternative futures or scenarios. Included in this presentation is an examination of the gains and losses experienced by consumers and by individual industries which spend and/or receive funds for pollution abatement.

Wherever possible, the national pollution abatement costs, the economic impacts and tradeoffs, and the associated environmental changes that have been estimated and presented in this report are those that would not have occurred without Federal legislation. Specifically, it is assumed that, in the absence of the two laws, the amount of pollution discharged per unit of production (or per person for sewage, or per mile for vehicles) would have remained the same as in 1971. A pre-legislation baseline, defined in terms of 1971 pollution control technology levels, is thus established, and all costs, impacts, tradeoffs, and environmental changes are measured as differences from that baseline.

Problem Overview

Both the comprehensive assessment of pollution control and also the industry-by-industry estimates of pollution control expenditures and pollution reduction are presented at the national level. Although more detailed information is provided in some instances, this information is presented primarily to enhance an understanding of the basis established for the national aggregated estimates.

Estimating the control costs and the quantities of pollutants produced on a national basis is a complicated process. Not only are there a large number of pollution sources, but each source could emit a number of pollutants that can be controlled separately or jointly by several alternative control technologies. Conversely, each specific pollutant can be traced to a considerable number of different sources. The costs of control are most conveniently estimated by source, even though they will usually cover more than one pollutant for each source. On the other hand, levels of pollution are more easily examined by pollutant; these levels are estimated by aggregating emissions by pollutant across all sources of that pollutant.

A general overview of the relationships among sample sources, pollutants, effects, and control technologies is presented in Table 1. Discussions of these relationships are found for each industry affected by Federal pollution control legislation in Sections Two and Three of this report.

Table 1.
Overview of Sample Pollution Control Relationships

Medium	Source	Pollutant	Effects	Control Technology
Air	Automobiles	NO_x, HC, CO	Smog, Lung Damage	Engine Modification, Catalysts
	Electric Utilities	SO_x	Respiratory Problems	Scrubbers, Fuel Switching
		Particulates	Soiling, Reduced Visibility	Electrostatic Precipitators, Filters
	Industry			
	Sulfuric Acid	SO_x	Respiratory Problems	Absorption
	Petroleum	HC	Smog	Floating Roof Tanks
	⋮	⋮	⋮	⋮
Water	Municipal Sewers	BOD	Dissolved Oxygen	Oxidation, Adsorption
		Suspended Solids	Materials, Fish Damage	Sedimentation, Filtration
		Pathogens	Infection	Disinfection
	Industry	BOD	Dissolved Oxygen	Oxidation, Adsorption
		Suspended Solids	Materials, Fish Damage	Sedimentation, Filtration
		Dissolved Solids	Materials Damage	Ion Exchange
		Acids	Materials Damage	Neutralization
		Toxics	Poisoning	Adsorption
	⋮	⋮	⋮	⋮

Assumptions

The Federal pollution control legislation ultimately requires industries, consumers (transportation vehicles), and municipalities to lessen or completely eliminate their discharges of pollutants into the nation's atmosphere and waterways. Hence, these pollution contributors must spend a portion of their money resources for pollution abatement regardless of the state of the economy. However, pollution control expenditures are not independent of the state of the economy because the level of economic activity affects the level of production, which in turn affects the amount of pollution generated by industries, consumers, and municipalities. Consequently, the forecasts of pollution control expenditures are based on corresponding forecasts of national economic activity.

Forecasts of pollution control expenditures must also be based upon explicit assumptions about the rate of compliance with pollution control legislation. The assumed timetables for installing pollution abatement equipment are given later in this Introduction as part of the compliance assumptions for this report. All cost estimates presented in this report are expressed in 1975 dollars unless otherwise noted. In addition, annual costs apply to calendar years unless specified differently.

ECONOMIC ASSUMPTIONS

A consistent set of economic assumptions is the basis for the cost estimates presented in this report. These assumptions were used to produce a "Reference Case" forecast of the U.S. economy and are summarized in Table 2. An alternative set of economic assumptions is presented in Section Four; the pollution control cost and pollutant discharge estimates corresponding to this alternative scenario enable us to evaluate possible variations from the Reference Case estimates introduced by different economic assumptions.

ENERGY ASSUMPTIONS

The energy assumptions for Reference Case pollution control forecasts are taken from the Federal Energy Administration's "Business as Usual" scenario in the November 1974 Project Independence Report where the import price for oil is $7 per barrel; they are summarized in Table 3.

Table 2.
Reference Case Economic Assumptions

Economic Assumption	Government Agency	Values
Population-Series E Projections (Millions of People)	Bureau of the Census	1975-213.9 1980-224.1 1985-235.7
Labor Force (Millions of People)	Bureau of Labor Statistics	1975- 93.8 1980-101.8 1985-107.7
Labor Productivity	Bureau of Labor Statistics	Varies by Industry
Gross National Product (Trillions of 1975 Dollars)	Council of Economic Advisors (1975-1980) Bureau of Labor Statistics (1980-1985)	1975-1.47 1976-1.57 1977-1.69 1978-1.81 1979-1.85 1980-1.99 1985-2.40
Forecast Time Period	EPA	1/1/76 - 12/31/85
Unemployment Rate in 1985 (Full Employment Economy)	Bureau of Labor Statistics	4.5%
Nominal Interest Rates	Office of Management and Budget	Public-10% Private-10%
Federal Expenditures in 1980 and 1985 Excluding Transfers and Pollution Control Programs. (Millions of 1975 Dollars)	Department of Commerce, Bureau of Economic Analysis	1980-$156,400 1985-$173,400
Federal Expenditures for Pollution Control	EPA	

Table 3.
United States Total Gross Consumption of Energy Resources (In Trillions of Btu's/Year) (Business-as-Usual Without Conservation-$7/Bbl Oil)

Fuel	1972	1977	1980	1985
Coal	12,495	16,854	18,074	19,888
Petroleum	32,966	37,813	41,595	47,918
Natural Gas	23,125	21,558	22,934	23,947
Nuclear Power	576	2,830	4,842	12,509
Other	2,946	3,543	4,014	4,797
TOTALS	72,108	82,598	91,459	109,059

Source: Project Independence Report, Federal Energy Administration, Appendix A1, p.37, November 1974.

AIR COMPLIANCE ASSUMPTIONS

EPA regulations and Federal legislation related to the Clean Air Act of 1970 apply different levels and modes of air pollution controls to these specific pollution source categories: mobile sources (transportation vehicles), existing stationary sources of air pollution, new stationary sources of air pollution, and sources of hazardous pollutants. The Clean Air Act and the cost estimates presented in this report are based on the principle that pollutant emissions will be brought under whatever level of control is necessary to achieve national primary ambient air quality standards. However, for many different reasons, many industries have not met the July 1, 1975, compliance date originally set for existing stationary sources. Similarly, the original dates and standards established for transportation vehicles have been changed. The specific assumptions for each source category are described below:

1. Mobile Sources (Transportation Vehicles). The emissions standards and the compliance schedule which must be met by mobile sources are presented in Section Two of this report (see Mobile Sources and State Transportation Control Plans). The assumed compliance dates reflect the delayed implementation of standards for reduced hydrocarbons, carbon monoxide, and nitrogen oxide emissions

from light-duty vehicles as proposed in 1977 amendments to the Clean Air Act passed by both houses of Congress.

2. Stationary Sources (Existing). Stationary sources of air pollution (industrial plants, electric utilities) which existed at the time of passage of the Clean Air Act are regulated by approved State Implementation Plans (SIP's). The standards assumed for each industry and for utilities are given in the industry summaries in Section Two of the report. Most SIP's require compliance by July 1, 1975, but achievement of this goal would imply a peaking of investment which did not occur in 1974 and 1975. Hence, except for sulfur dioxide control by electric utilities, all existing stationary sources are assumed to be moving toward full compliance at an extended expenditure rate, as given in the Summary for Section Two. A compliance date of January 1, 1981, is assumed for sulfur dioxide from utilities.

3. Stationary Sources (New). New sources of air pollution include new industrial plants built since the passage of the Clean Air Act and also existing plants which have made certain modifications in their facilities. These sources are assumed to comply with EPA New Source Performance Standards (NSPS) except where such standards have not yet been developed or where SIP standards are more stringent. In these latter two cases, SIP standards are assumed. New pollution sources are assumed to be in compliance with these standards when they go into operation. The exact standards being assumed are given in the appropriate sections in Section Two.

WATER COMPLIANCE ASSUMPTIONS

Unlike the Clean Air Act, the 1972 Amendments to the Federal Water Pollution Control Act prescribe full Federal regulation of water pollutant sources, except as redelegated to specified states. In addition to setting ambient water quality standards to be met by 1983, the Act specifies the levels of control technology to be utilized by industrial and municipal pollution sources by July 1, 1977 and by July 1, 1983. EPA has defined these technologies for most major industrial pollution sources in effluent guidelines documents. It enforces the act through permit programs in 40 states, the remaining 10 having been delegated authority for state enforcement. The provisions of the act and the compliance assumptions for this report are enumerated below.

1. Industrial Sources.

   a. Industries discharging pollutants into the Nation's waters in 1972 will adopt the best practicable pollution control technology (BPT) by January 1, 1978, and the best available technology (BAT) by January 1, 1984. These dates have been pushed back six months from those specified in the act to allow the analysis for this report to be done on a calendar year basis.

   b. Industries for which BPT and BAT are not defined in EPA guidelines are assumed to adopt control technologies similar to those of related industries covered by the guidelines. Specific control technology assumptions for water polluting industries investigated by this report are provided in Section Three.

   c. Industries discharging their wastewater into municipal treatment plants must (and it is assumed they do) pretreat their effluents so that industrial pollutants do not interfere with plant operation and do not pass through the treatment process without adequate treatment. Pretreatment technology must be operating by January 1, 1978. Pretreatment is assumed to be unnecessary for those industries for which pretreatment guidelines have not been prepared.

   d. All new sources of water pollution (usually plants constructed since 1974) are assumed to comply with EPA NSPS guidelines.

2. Municipal Sources.

   Compliance with the Federal Water Pollution Control Act by all publicly owned sewage treatment plants in existence on July 1, 1977, would require them to achieve a secondary treatment level for all effluents or more stringent treatment where required by water quality standards. Because of the difficulty facing the municipalities in raising capital and limitations in Federal construction grants, treatment plants cannot be built at a fast enough rate to assure compliance with the Act. Instead, it is assumed in this report that new plants will only be built as rapidly as permitted by Federal appropriations and state and local matching funds, which are proposed as shown in Table 4. These capital outlays represent actual expenditures, which lag behind the schedule of construction grant awards to municipalities. Section Three discusses the relationship between these appropriated funds and the expenditures which would be necessary to comply with the act.

These economic, energy, and compliance assumptions and other less quantifiable policy variables are further discussed in Section Four.

Table 4.
Direct Capital Outlays for Construction of
Publicly Owned Sewage Treatment Plants
(Federal, State, & Local)
(In Millions of Appropriated Dollars)

	Fiscal Year	Calendar Year
1975	2,773	3,201
1976	3,628	4,499
Transition[1]	1,280	
1977	5,623	5,927
1978	6,837	6,517
1979	5,558	4,877
1980	2,833	2,377
1981	1,010	907
1982	598	511
1983	251	251
1984	251	251
1985	251	251

[1] This "transition period" represents the months of July through September 1976; all subsequent Fiscal Years will run from October 1 through September 30 of the following year.

3. Elimination of Discharge.

Although Elimination Of Discharge (EOD) is specified as the goal of the Water Pollution Control Act, it is not currently required by regulations except for those industries where BAT is the same as EOD. Consequently, EOD is not assumed for the pollution control cost estimates appearing in this report.

POLLUTION CONTROL COSTS:
DEFINITIONS AND CALCULATION METHODS

The various costs presented in this report are described below, and the general approach used to estimate costs in each of three major categories is discussed. The three categories are direct costs, government program expenditures, and indirect costs.

Direct Costs

The expenditures associated with acquiring, owning, and operating the buildings and equipment needed to control pollution are direct costs. These costs are directly incurred by industries and municipalities to reduce pollutant levels; they include investment costs, operation and maintenance costs, and the costs incurred to borrow the necessary capital funds.

INVESTMENT COSTS

These costs include all expenditures for pollution control equipment and associated modifications or additions to buildings. They are the actual cash outlays used to purchase and install the equipment and to construct the buildings or building changes. In the case of municipal treatment plants, the cost of building the whole plant is an investment cost for pollution control. These costs do not include those charges made by a lending institution for borrowing the money, nor do they take into account the income tax writeoff benefits which accrue to an industry due to depreciation.

OPERATION AND MAINTENANCE (O&M) COSTS

The annual costs of operating and maintaining the pollution control equipment and plant include expenditures for:

1. Materials used by the equipment (e.g., chemicals)

2. Labor for maintenance and repairs

3. Energy

4. Materials for repairs

5. Overhead

6. Monitoring (labor)

7. Byproduct credits.

TOTAL ANNUAL COSTS

Total annual costs are those costs incurred each year by industry or government (municipalities) in owning and operating pollution control equipment and plants. They are the sum of the O&M costs for the year and the annualized capital costs for the year. Note that annualized capital costs are not the same as the investment costs discussed above. Annualized capital costs are derived by amortizing the initial investment over the life of the facility, and can be thought of as the annual amount needed to repay the loan with interest over a specific time period.

COSTING METHODOLOGY

The direct costs of air and water pollution control are reported separately for each source and source category. For air pollution, the major source categories are: (1) stationary sources, comprising industries, power utilities, and space heating; and (2) mobile sources, namely, automobiles, trucks, and aircraft. The major source categories for water pollution are: (1) point sources, which include municipalities, industries, power utilities, and runoff from urban areas; and (2) nonpoint sources, which include runoff from mining and drilling operations, and agricultual crop production activities. Because urban runoff and nonpoint-source pollution control is a far more complex problem and an established regulatory procedure such as effluent permits is not yet developed, control costs for these sources could not be reliably estimated, and hence, are not reported in this document.

The details of calculating costs differ among the major source categories. In general, the procedure for each source is:

1. Examine the regulations to determine the emission or effluent standards to be met.

2. Select from the alternative technologies those pollution control methods that are likely to be employed.

3. Estimate the cost of using these methods for representative units (plants, vehicles, etc.).

4. Multiply these unit estimates by the total number of such sources in the nation that are anticipated to require control in the appropriate year. Thus, for automobile emission controls, the cost of an individual control system is multiplied by the total number of automobiles estimated to be sold in the appropriate year with that system.

This procedure, which is more complicated for industrial sources, is outlined below and is discussed more thoroughly in Section Four of this report:

1. Total industry production capacity is inventoried or estimated.

2. Unique production processes within the industry which emit differing levels of pollutants and/or require different control techniques are identified.

3. For each production process, the applicable abatement control technologies are identified and the percentage of plants using each technology is specified.

4. For each control technology associated with a given production process, the percentages of plants covered by different state implementation plans are estimated (for air control cost calculations only).

5. Usually from one to three typical plant sizes for each given implementation plan, control technology, and production process combination within the industry are defined. (This combination is hereafter referred to as an industry segment.)

6. The capacity for the industry segment is allocated among the plant sizes, and capital and O&M costs are developed for a typical plant of each size in the segment, depending on the standard it must meet. (This depends in part on whether it is a new or existing plant.)

7. The costs are applied to all plants of the same size within the segment; then costs for the different size classes are summed to obtain total capital and O&M costs for the segment. This is done for each segment of each production process within the industry. Control costs for the industry are obtained by

totalling all the capital and O&M costs computed for the industry's segments.

The costs associated with building and operating municipal wastewater treatment plants for this report are directly related to the Federal appropriations and state matching funds available to build new plants rather than costs for fully meeting regulations as in the industrial case. These full costs have, however, been estimated in six "Needs" categories. These categories relate to the Municipal Needs Survey (Final Report to the Congress, "Cost Estimates for Construction of Publicly-Owned Wastewater Treatment Facilities", February 1977), which was conducted by EPA to determine the physical facilities needed by municipalities to adequately handle their sewage treatment problems; the categories are:

- Category I - Secondary treatment required.
- Category II - More stringent treatment required by water quality.
- Category IIIA - Correction of sewer infiltration/inflow.
  IIIB - Major sewer rehabilitation.
- Category IVA - Collector sewers.
  IVB - Interceptor sewers.
- Category V - Correction of combined sewer overflows.
- Category VI - Treatment and/or control of stormwaters.

Government Program Expenditure

Program costs which are incurred by governmental agencies in carrying out pollution control legislation include expenditures for planning, administration, enforcement, and research grants. These costs are incurred at all three levels of government: Federal, state, and local. The costs of constructing, operating, and maintaining control equipment owned by these governments are direct costs, and, as such, are included in the air and water program costs discussions in Sections Two and Three, respectively.

AIR PROGRAM COSTS

Government program costs for air pollution control have been estimated separately for Federal and non-Federal programs.

Federal programs involve two types of funds: grant funds, which are passed on to state and local governments; and in-house funds, which are expended by a Federal agency or by its contractors. Estimates of projected grant expenditures are obtained from the relevant agencies, primarily from EPA, which accounts for the vast majority of grant funds, and from the Appalachian Regional Commission and the Department of Transportation, which account for most of the remainder. Estimates of projected in-house expenditures are based upon Fiscal Year 1976 outlays.

The basic procedure used for estimating program expenditures by state and local governments makes use of available data for 15 representative states. The estimated ratios of expenditures for various functional areas, such as enforcement and engineering, are first derived for these states and are then applied to all other states based on the similarity of industrialization, geography, population, and general air pollution control policies.

In general, sources of data for projecting government program costs for air pollution abatement beyond 1979 were not available. Instead, extrapolations were made from baseline data on the basis of several reports that provided forecasts of future government expenditures for specific program components.

WATER PROGRAM COSTS

The major assumptions underlying the 10-year water program projections are:

1. Future year estimates are a continuation of the estimated Fiscal Year 1978 program level.

2. No new major legislative amendments will be made to the Federal Water Pollution Control Act.

As with the air program expenditures, Federal water program expenditures are divided into two general categories: Assistance Programs, which administer Federal grants; and Regulatory Programs, which include all other Federal administration and enforcement expenditures.

The 10-year state program expenditure projections are derived from the requirements under the 1972 Amendments of the states to issue permits, review construction grants, and monitor compliance. Permit costs are developed for each major category of activity. State agencies perform a variety of additional activities over and above those needed to comply with Federal requirements; the expenditures for these activities are not included here. In addition, there is no provision for program expenditures for nonpoint-source control activities.

Indirect Costs

Indirect costs are those experienced by government, business, or consumers as a result of having to bear the direct costs of pollution control. The added industrial costs for pollution control must either be passed on to the consumer in the form of increased prices or be absorbed by industry in reduced profits. Where investment requirements are high and profits are already low, some marginal plants might find it impossible to continue operation in the face of pollution control requirements. The resulting plant closures may thus result in local unemployment problems.

This report examines some of the indirect macroeconomic effects of pollution control at the national level. Thus, Section Four presents an analysis of the impact of control costs on aggregate production, investment, employment and other national accounts.

EPA's Office of Planning and Evaluation conducts detailed economic impact analyses for some major industries: e.g., Steel, Electric Utilities, Nonferrous Metals, Petroleum Refining, Chemicals, and Pulp-and-Paper. These studies cover the effects of current and proposed emission and effluent standards on prices, profits, production, productivity, plant closures, and employment for each industry, at both national and regional levels.

COMPREHENSIVE ASSESSMENT

The primary reason for assessing the costs, benefits, and impacts of air and water pollution control resulting from Federal legislation and regulations in the same report is to make possible analysis of total impacts on the economy, including changes in the interrelationships among the various elements and sectors of the economy. Another consequence of the combined report is the capability of estimating the total pollution control costs for a single industry and their likely impact on that industry. For this report, a comprehensive, impact estimation and analysis system has been used to examine the comprehensive impacts of pollution control, at both national and industry levels. This system, the Strategic Environmental Assessment System (SEAS), is summarized in Section Four.

Alternative scenarios are run with SEAS to study the relative consequences of meeting Federally legislated controls under alternative assumptions about the future. A comparative analysis procedure, which builds upon the Reference Case forecasts described previously, is then used to assess the results. Scenario assumptions, scenario run results, and comparisons among scenarios are presented in Section Four.

As noted earlier, pollution control expenditures are not independent of the state of the economy. Similarly, the impact of these expenditures on the economy, the environment, and energy consumption depend on the initial assumptions made about the future in each of these areas. Hence, the objective in this report is not to predict exactly what the impacts of pollution control will be over the next 10 years, but rather to conditionally forecast their relative magnitude and interrelationships. The analysis focuses on how impacts vary as basic assumptions about future economic activity and energy policy are differentially changed.

The comparative analysis scheme used to assess the economic and environmental impacts of pollution control in this report takes into account that various experts may hold differing views about future U.S. economic growth, economic composition, and energy consumption. By exploring the impacts of a range of reasonable assumptions about the future, one is able, by this approach, to determine how sensitive the economy, the environment, and energy budgets are to alternative actions.

ALTERNATIVE FUTURES

Assumptions for several alternative futures or scenarios are defined in Section Four of this report. These scenarios provide the basis for the comprehensive assessment of pollution control impacts on the economy and the environment also presented in Section Four. Although one forecast has been termed the Reference Case, it should not necessarily be interpreted as a prediction of the most realistic future. Rather, it is the benchmark or reference against which the comparative analysis was conducted. Assumptions for the Reference Case are essentially those enumerated earlier in this Introduction. They describe a high productivity/high growth-oriented economy where full employment is reached in the early 1980's.

Other alternative scenarios considered in Section Four are briefly described below.

1. **The Low Productivity Scenarios.** These scenarios are based on time series projections of labor productivity from 1952 to 1971 made by the developers of the INFORUM input-output model of the economy used in SEAS. They reflect a slowing down of productivity because of shifts toward service industries in the pattern of final demand, and because of a slowing down of the productivity increase rates in other industries. GNP estimates which correspond to these assumptions are shown in Table 5 compared with those for the Reference Case.

Table 5.
Comparison of GNP Estimates for Low Productivity and Reference Case Scenarios
(In Trillions of 1975 Dollars)

	Low Productivity GNP	Reference Case GNP
1975	1.53	1.47
1977	1.65	1.69
1980	1.84	1.99
1983	1.99	2.23
1985	2.08	2.40

2. **The Energy Conservation Scenarios.** These scenarios comprise a variation of the Reference Case in which energy consumption is reduced through selected conservation measures. It is based on the Federal Energy Administration's "Business-as-Usual with Conservation" scenario where the import price of oil is $11 per barrel. (See Appendix A1, page 46 of the November 1974 Project Independence Report.) The energy usage composition projected by Project Independence is not exactly matched because of

differences in energy demand resulting from the redistribution of monetary savings to consumers.

Two scenarios are run and analyzed for each set of economic and energy-related assumptions. The first scenario in each case is used to develop a set of forecasts on the economy, industry output, environmental residuals, and energy budgets given no increase in pollution control beyond that present in 1971. The same parameters are then forecast in a second scenario, with pollution controls, costs, and equipment punchases superimposed on the original economic assumptions as necessary to comply with Federal legislation. This procedure results in six major scenarios:

	Without Abatement Costs	With Abatement Costs
Reference Case	Scenario 1	Scenario 2
Low Productivity	Scenario 3	Scenario 4
Energy Conservation	Scenario 5	Scenario 6

The scenarios are then paired for a comparative analysis of relative impacts and tradeoffs in the following manner: (1,2) (1,3) (1,5) (2,4) (2,6) (3,4) (5,6). A subset of Scenario 2, which assumes a continuing appropriation of $7 billion a year for municipal sewage treatment facilities, is also compared with Scenarios 1 and 2. In addition to these analyses, which are presented in Section Four, Section One includes a study of the cost savings resulting from process change as compared with Scenario 2 control costs.

Chapter 2

The Benefits of Pollution Control Programs

Pollution control legislation has traditionally favored rigid standards, either to control the discharge of pollutants into air and water or to maintain ambient quality levels. While it was not possible to base such legislation on an analytical estimation of the full benefits that would result, its enactment reflected the judgement that the overall benefits to society were great enough to justify the necessary costs. Federal legislation also recognized the need for more elaborate and more accurate assessment of the costs and benefits of such programs, both for their implementation and for future consideration of additional legislation.

The purposes of such an assessment transcend the emphasis often given to the techniques for quantifying benefits and their numerical results, important though they may be. The purpose of cost-benefit analysis is to provide the type of information on the value of public investments that the market system provides on the value of private investments. However, public investments usually have many objectives in addition to those easily measured in dollars and cents. Still, the process of logical and systematic scrutiny that is inherent in the accepted methods of cost-benefit analysis can contribute greatly to society's ability to improve its well-being by allocating more efficiently its limited resources.

Thus, a major purpose of this discussion of the national benefits of air and water pollution control is the achievement of a more precise understanding of the nature, sources, and approximate magnitude of such benefits. Such an understanding, when shared by legislators, program managers, and the public, may well be of greater value than the numerical results themselves.

DEFINITION OF BENEFITS

Benefits of controlling air and water pollution derive from the reduction of damages caused by air and water pollution. The measurement of benefits is performed in terms of the damages that would otherwise be incurred. A basic concept in benefit evaluation is willingness to pay, which can be defined as the highest price that individuals would be willing to pay to obtain the improvement in air or water quality resulting from a given pollution control program. Benefits are evaluated whenever possible in monetary terms because it provides a common measure of all the types of benefits and costs. The corresponding economic damages result in out-of-pocket losses caused by increasing the costs of using air and water, by decreasing the level of use of the resource, and by increasing costs of avoiding or repairing the effects of pollution.

Many types of benefits are not amenable to quantification in monetary terms because of their nature and the state of the art of available measurement methods. This is the case with "psychic" damages, so labeled because they relate to the pleasure or displeasure associated with the use of the air and water in our environment. Psychic damages include decrease or loss of pleasure from the use of air or water that has become polluted, and the increased experience of displeasure, pain, and anxiety, as well as the so-called option, preservation, and vicarious values experienced by non-users.

Option values arise because people are willing to pay to ensure the availability of clean air and water, even if they are uncertain when or how they would actually use it. Preservation values arise in a similar fashion, when people are willing to pay for the preservation of a resource, even when they are certain that they will never use it directly. Both preservation and option values are frequently associated with a unique environmental resource, for which no substitute exists. Preservation value can also be associated with risk aversion, in which a value is placed on the reduction in the probability of the loss of an environmental resource through extinction of a species or collapse of an ecological system.

Finally, the term vicarious satisfaction has been used to describe the motivation of people who are willing to pay to provide benefits for their fellow citizens rather than for themselves, and bequest value describes the similar benefit derived by individuals preserving an environmental resource for future generations. Although all these psychic values and the corresponding damages caused by pollution are currently not easily measured, they apparently account for a significant portion of the total value of pollution control to society.

In general, estimation of benefits resulting from alternative pollution control programs calls for four steps:

- Estimate the amounts of pollutants produced by projected economic activity.
- Estimate the remaining discharge of pollutants to the environment after imposition of specified control measures.
- Estimate the ambient air or water quality that results from the diffusion and assimilation of pollutants by the environment.
- Estimate the nature and magnitude of resultant reduced damages and the corresponding benefits.

The first two steps involve the projection of a suitable economic scenario and evaluation of the cost-effectiveness of various administrative and technological pollution controls. The third step requires the use of complex models of the diffusion and assimilation of specific pollutants. The last step relies on the development and interpretation of dose-effect factors or damage functions, which are discussed in the next section.

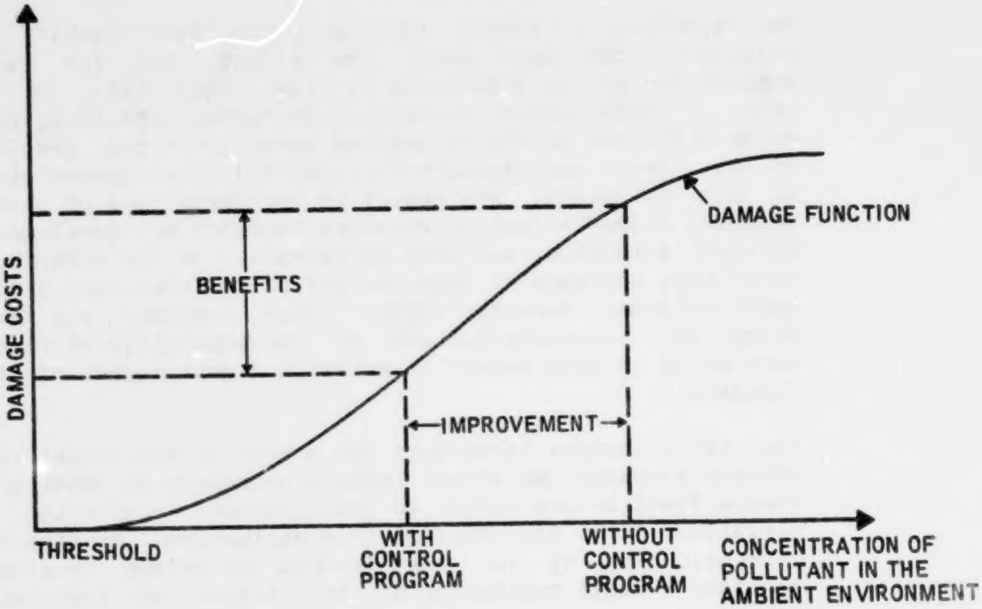
Finally to the extent that they were developed for specific cases, estimates must eventually be aggregated over the pollutant/effect combinations, geographic regions, and time periods of interest.

PHYSICAL AND ECONOMIC DAMAGE FUNCTIONS

A damage function is the quantitative expression of a relationship between exposure to specific pollutants and the type and extent of the associated effect on a target population. Exposure is typically measured in terms of ambient concentration levels and their duration, and it may be expressed as "dosage" or "dose". The former is the integral of the function defining the relationship between time and ambient level to which the subject has been exposed. Dose, on the other hand, represents that portion of the dosage that has been instrumental in producing the observed effect (e.g., the amount of pollutants actually inhaled in the case of health effects of air pollution).

The effect can become manifest in a number of ways and can be expressed in either physical and biological or economic terms. If the effect is physical or biological, the resultant relationship is known as a physical or biological damage function, or a dose-effect function. On the other hand, an economic damage function is expressed in monetary terms. Economic damage functions can be developed by assigning dollar values to the effects of a physical or biological damage function, or by direct correlation of economic damages with ambient pollutant levels. A representative economic damage function, showing the benefits corresponding to a given improvement in environmental quality, is presented in Figure 1.

Figure 1.
Damage Function



The S-shaped damage function is rather characteristic of the relationships between pollutant exposure and resultant effect. The lower portion of the curve suggests that, up to certain pollutant ambient values, known as threshold levels, there are no measurable damages, while the upper portion indicates that there is a saturation level (e.g., death of the target population), beyond which increased pollutant levels do not produce additional damages. Between these segments is a range where damages are roughly proportional to the concentration of pollutants.

In reporting a damage function, one must specify the pollutant, the dose rate, the effect, and the target population, or the population at risk. Dose rate, or the rate at which ambient concentration varies with time, has a major influence on the nature and severity of the resultant effect. Long-term exposure to relatively low concentrations of air pollutants may result in manifestations of chronic disease, characterized by extended duration of development, delayed detection, and long prevalence. On the other hand, short-term exposure to high concentration levels may produce acute symptoms characterized by quick response and ready detection. Characterization of the population at risk is considered in more detail in subsequent paragraphs of this discussion.

The two principal techniques for analyzing the relationship between exposure and effect indices necessary to construct a damage function are known as multivariate regression and nonparametric or distribution-free estimation. Multivariate regression is by far the favored technique because it provides a rapid indication of the degree of association between a large number of independent and dependent variables and is readily programmable for computer operation. However, its validity is heavily contingent on a fairly precise *a priori* definition of the relationship between each independent and dependent variable, and on precise measurement of the independent variables. Thus, this technique is especially vulnerable to the poor precision in measurement and reporting of air pollution levels for a given segment of population. Nonparametric estimating is free of these assumptions, but it calls for laborious data reduction for each of the many pairs of independent and dependent variables, and expert judgement to guide each step of the process. Moreover, this technique requires sufficient data for each independent variable to isolate and remove the influence of likely interfering factors.

The data required to construct damage functions can be obtained by the following approaches:

- Epidemiological or field studies and observations
- Toxicological or laboratory investigations
- Market studies
- Delphi method
- Public opinion surveys
- Legislative decisions
- Litigation surveys.

The first two approaches are attuned to physical damage functions, while the remaining ones are directed toward derivation of economic relationships.

The first approach involves the comparative examination of the effects of pollutants on large segments of population exposed to different levels of pollution in order to deduce the nature and magnitude of the likely effect. Field studies and observations represent the same approach to assessment of effects on animals, vegetation, and materials, and they are characterized by similar analytical techniques and concerns. Toxicological studies involve deliberate administration of controlled doses of pollutants to animal subjects, followed by observation of the resulting effects. Laboratory studies represent essentially the same approach for determining effects of pollutants on plants and materials.

Two considerations need to be noted about epidemiological and field studies. First, it is very important to remove or control the influence of factors other than pollution that may be responsible for the different effects observed. In the case of health effects, for example, these include physiological, genetic, and other characteristics of the population under observation, such as age, sex, race, family medical history, occupational exposure, medical care, state of health, and nutrition. When these characteristics cannot be factored out, it is frequently assumed that their distribution is sufficiently uniform in the populations under observation that the basic results are not affected significantly. Secondly, epidemiological and field studies and observations can only indicate an association between exposure to pollution and the observed effect, though the impact of an association can be strengthened considerably through evidence of consistency and specificity of the relationship. A causal relationship can be demonstrated, or made plausible by toxicological and laboratory studies, or by the construction of a plausible connective mechanism.

Market studies, such as those investigating differences in property value or income, employ prices or wages as an indication of the values affected by pollution, and their usefulness has been demonstrated in a number of cases. This approach is heavily dependent on the investigator's ability to identify and isolate the many other factors that affect the value of property, or other indicators used. In the Delphi method, the knowledge of a diverse group of experts is pooled for the task of quantifying variables that are either intangible or shrouded in uncertainty. This method provides an efficient way to obtain subjective, but informed, judgements. Thus, in a recent project, the California Air Resources Board under EPA sponsorship constructed a number of dose-response functions based on expert opinions submitted by a group of clinicians and other health effects researchers.

Surveys of public opinion focus on estimating indivudal preferences and demands. Such surveys have been particularly helpful in understanding how attitudes about pollution are formed and affected by changes in environmental quality. They can also provide an indication of what people may be willing to pay for enhancement of environmental quality, or perhaps, what their preference might be for the reduced risk of experiencing certain adverse effects. Surveys of legislative decisions or litigation awards can also provide some insight into the perceived value of pollution abatement.

POPULATION AT RISK

In the past, it was customary to assess the severity of air pollution in terms of point-source emissions, and later, in terms of ambient concentrations. These indicators reflected the progression in the state of the art from visual assessment of smoke plumes to increasing availability of air quality monitoring stations and associated data processing capabilities. However, the real significance of air pollution lies in its physical, economic, and social impact on the affected population.

Beyond this, characterization of the population at risk in terms of its potential susceptibility to various levels of air pollution can provide useful indications for allocation of resources and setting of priorities in air pollution abatement. For example, a higher clean-up priority could be assigned to an area containing a large population of older people or those exposed to high occupational pollution than to another area with a smaller population of relatively healthy people not otherwise exposed to harmful pollutants. This procedure can be refined further through control of specific pollutants.

Since the importance of characterizing the population at risk to various levels of air pollutants became recognized, there have been several attempts to obtain such a characterization through crude regional estimates. The first comprehensive, national assessment was only recently completed. The major assumptions and findings of this study are summarized here.

The specific objective of the population at risk study was to calculate the number of people in selected demographic and socioeconomic classes who are exposed to various levels of several air pollutants. This was accomplished in six steps:

- Select air quality indices
- Select population indices
- Select air quality and population coverage units
- Obtain and process air quality data
- Obtain and process census data
- Calculate population at risk.

The pollutants selected were total suspended particulates, sulfur dioxide, nitrogen dioxide, carbon monoxide, and photochemical oxidants. The air quality indices were expressed in terms of the relationships of pollutant ambient levels to their corresponding short-and long-term primary standards. They were divided into four classes: 0-75 percent, 75-100 percent, 100-125 percent, and above 125 percent of the corresponding primary standard. In the case of short-term standards, the 90th and 99th percentiles of the observed values were found to be more useful indicators than the maximum values.

Human susceptibility and resultant response to toxicological and physical stress produced by air pollutants is determined somewhat by certain intrinsic traits, such as age, race, sex, and general health, as well as by such extrinsic characteristics as employment, income, educational level, and general environmental conditions. The population classes selected for the study are listed below:

- **Age:**
  - Under 19 years
  - 20-64 years
  - 65 years and over
- **Race:**
  - White
  - Black
  - Other
- **Employment:**
  - Manufacturing
  - Other
- **Family income:**
  - Under $5,000
  - $5,000-$24,999
  - $25,000 and over

Although population information from the U.S. Bureau of the Census is available for the entire country, air quality data, stored in EPA's National Aerometric Data Bank, are not. The gaps occur in the form of specific pollutants, the short-term or long-term values, or missing stations. Consequently, this study dealt with 241 standard metropolitan statistical areas (SMSAs), which cover 68.6 percent of the population and 11.0 percent of the land area of the United States. Pollutant ambient levels in these areas were derived by plotting isopleths (equal concentration contours) between air quality monitoring stations and by superimposing this display over maps of the SMSAs. The year of coverage for air quality data was 1973, though the population information was based on the 1970 U.S. census.

Finally, the population at risk was computed within each pollutant and population class, and aggregated to state, regional, and national levels. The results are displayed in tables of population versus air quality classes for different combinations of pollutants and geographic locations. The national aggregations for all five pollutants are presented in Tables 1 through 5.

The study concluded that the exposure of the U.S. population surveyed to short-term particulate, short and long-term sulfur dioxide, and short-term carbon monoxide levels was within the respective permissible primary air quality standards. On the other hand, significant portions of the population surveyed were exposed to excessive long-term particulate (31 percent), long-term nitrogen dioxide (24 percent), and short-term oxidant (58 percent) levels.

Table 1.
Population Characterized by Socioeconomic and Demographic Factors Exposed to Total Suspended Particulates
(1,000 persons)

Area: United States

Air Pollutant: Total Suspended Particulates

Air Quality Index: Short Term - 90th percentile of 24 hour data
Long Term - Annual geometric mean

Population Characteristics	Air Quality Level Classes - $\mu g/m^3$									
	Short Term					Long Term				
	< 200	201-260	261-320	321-450	> 451	< 60	61-75	76-90	91-120	> 121
A. General										
Age: 0-19	47,850	2,004	471	142	105	19,889	10,621	7,054	4,040	2,759
20-64	68,437	2,717	631	205	139	28,434	16,694	8,350	6,862	4,006
65 and over	11,644	462	116	44	19	4,442	2,874	1,650	1,196	670
Race: White	110,532	4,261	904	335	214	47,564	25,309	13,762	10,265	6,443
Negro	14,836	859	301	50	47	4,527	4,553	3,006	1,992	808
All other	1,672	63	13	6	2	664	327	286	360	184
B. Economic										
Annual family income: (thousands of families)										
$0-$4,999	5,271	265	66	22	13	1,760	1,312	612	631	394
$5,000-$24,999	25,093	962	224	66	52	10,644	6,027	3,220	2,107	1,644
$25,000 and over	1,876	50	6	3	1	964	400	196	141	111
C. Labor Force										
Percentage in manufacturing	25.4%	26.0%	28.8%	34.8%	18.1%	24.2%	25.1%	27.2%	26.9%	24.0%
D. Total Population	127,990	5,183	1,218	391	263	52,765	30,189	17,054	12,627	7,435

Table 2.
Population Characterized by Socioeconomic and Demographic Factors Exposed to Sulfur Dioxide
(1,000 persons)

Area: United States

Air Pollutant: Sulfur Dioxide

Air Quality Index: Short Term - 90th percentile of 24 hour data
Long Term - Annual arithmetic mean

Population Characteristics	Air Quality Level Classes - $\mu g/m^3$							
	Short Term				Long Term			
	< 260	261-365	366-420	> 420	< 60	61-80	81-100	> 100
A. General								
Age: 0-19	49,283	62	2		37,403	399	167	1
20-64	70,412	93	3		53,534	566	214	1
65 and over	12,174	19	1		8,887	118	29	0
Race: White	113,073	161	3		83,931	928	393	2
Negro	16,032	12	3		13,133	145	15	0
All other	1,768	1	0		1,760	10	2	0
B. Economic								
Annual family income: (thousands of families)								
$0-$4,999	5,457	5	1		4,087	43	13	0
$5,000-$24,999	25,848	27	1		18,394	285	60	2
$25,000 and over	1,932	2	0		1,564	14	5	0
C. Labor Force								
Percentage in manufacturing	35.4%	43.0%	14.5%		26.3%	23.7%	26.2%	30.9%
D. Total Population	131,869	174			99,824	1,083	410	2

Table 3.
Population Characterized by Socioeconomic and Demographic Factors Exposed to Carbon Monoxide
(1,000 persons)

Area: United States

Air Pollutant: Carbon Monoxide

Air Quality Index: Short Term - 99th percentile of one hour data

Population Characteristics	Air Quality Level Classes - $\mu g/m^3$			
	< 30	31-40	41-50	>51
A. General				
Age: 0-19	37,356	246	242	191
20-64	64,394	420	407	292
65 and over	9,217	88	89	60
Race: White	96,944	506	509	453
Negro	12,257	127	183	47
All other	1,766	21	46	44
B. Economic				
Annual family income: (thousands of families)				
$0-$4,999	4,536	33	42	32
$5,000-$24,999	19,788	149	137	84
$25,000 and over	1,810	13	6	3
C. Labor Force				
Percentage in manufacturing	34.7%	13.6%	25.0%	31.7%
D. Total Population	100,967	754	738	543

Table 4.
Population Characterized by Socioeconomic and Demographic Factors Exposed to Nitrogen Dioxide
(1,000 persons)

Area: United States

Air Pollutant: Oxidants

Air Quality Index: Short Term - 99th percentile of one hour data

Population Characteristics	Air Quality Level Classes - $\mu g/m^3$			
	< 120	121-160	161-200	> 200
A. General				
Age: 0-19	11,262	6,011	11,326	10,726
20-64	15,900	7,128	16,946	15,306
65 and over	2,630	1,205	3,061	2,424
Race: White	24,909	11,690	26,378	25,008
Negro	4,149	1,576	4,540	2,888
All other	734	178	413	560
B. Economic				
Annual family income: (thousands of families)				
$0-$4,999	1,116	561	1,357	1,073
$5,000-$24,999	5,911	2,502	6,074	5,616
$25,000 and over	458	167	530	421
C. Labor Force				
Percentage in manufacturing	24.0%	21.2%	22.0%	21.3%
D. Total Population	29,792	13,444	31,333	28,456

Table 5.
Population Characterized by Socioeconomic and Demographic Factors Exposed to Oxidants
(1,000 persons)

Area: United States

Air Pollutant: Nitrogen Dioxide

Air Quality Index: Long Term - Annual arithmetic mean

Population Characteristics	Air Quality Level Classes - $\mu g/m^3$			
	< 80	81-100	101-125	>125
A. General				
Age: 0-19	6,268	1,697	2,233	220
20-64	9,034	2,470	3,374	460
65 and over	1,421	472	554	90
Race: White	15,024	3,649	5,364	535
Negro	1,195	966	577	183
All other	504	24	210	52
B. Economic				
Annual family income: (thousands of families)				
$0-$4,999	659	193	243	35
$5,000-$24,999	3,302	905	1,100	139
$25,000 and over	226	63	104	21
C. Labor Force				
Percentage in manufacturing	23.1%	30.1%	26.9%	27.0%
D. Total Population	16,723	4,639	6,161	770

PROBLEMS OF MEASUREMENT

Assessment of benefits of pollution control is beset by a number of major difficulties that have a profound effect on the accuracy and reliability of the benefit estimates. Some of these difficulties can be largely overcome with the aid of available ancillary information, while others require the expenditure of much additional effort. Still others must be dealt with by indirect estimation and other imprecise techniques. The more important problem areas may be listed as follows:

- Collection of reliable ambient quality data
- Selection of exposure indices and identification of synergistic effects
- Selection of representative populations
- Measurement of effects
- Establishment of causal relationships
- Presentation of non-quantifiable information
- Regional, demographic, and temporal extrapolation
- Consistent classification of damages
- Double-counting and omission of damages
- Assessment of damage reductions.

Collection of sufficient air and water ambient quality data requires a very large number of measuring stations and a commitment to measurement and data handling well in excess of the present level, because the problem concerns numerous point and nonpoint sources of pollutants discharging at irregular intervals into air and water. Consequently, the available data seldom reflect hourly, or even diurnal variations that may be important.

Collection of useful data on damages and their proper attribution to exposure to specific levels of various pollutants suffers from several handicaps. One is the problem of selecting the proper exposure index for each pollutant in terms of level, duration, and presence of other pollutants, or influence of meteorological and hydrological factors. Another is the need to select sample populations that are representative of the population at large in terms of susceptibility to detectable levels of damage. In the case of health effects, this involves segregation based on demographic and socioeconomic makeup of the population at risk.

A third difficulty lies in measuring the resultant effects. This is especially problematic in the case of psychic damages, such as those associated with health, recreation, aesthetics, option, and preservation values. Such damages are not adequately assigned costs by the market system because they are aspects of environmental use that are not owned privately or exchanged. Thus, estimation of the corresponding benefits requires development of proxy or surrogate measures.

The fourth and most formidable problem involves identifying and documenting a causal relationship between exposure to a given dose and production of a specific effect and deriving the corresponding damage function. The existing literature contains estimates for only a few discrete points on the many damage functions of interest. In order to produce national benefit estimates, it is frequently necessary to make major assumptions about the shape of the damage curve on the basis of these few points.

Most studies leading to the evaluation of damages resulting from exposure to various pollutants address a specific geographic area, population, and time frame. Extension to the national level and a more recent time frame requires extrapolations of ambient levels, population at risk, personal income, and increases in costs of resultant damages due to inflation. The classification of damages, for which the data are collected, is often dictated by availability of sources and analytical expediency, rather than a uniform and self-consistent framework. Consequently, different studies evaluate damages that are not necessarily additive or even comparable, and any effort to reconcile or aggregate the results of such studies must apply careful interpretive techniques to prevent gross overlaps or omissions of damage estimates. Moreover, in aggregating such fractional results, it is not currently possible to reflect the potential impacts of changes in one pollutant or one region on the damages caused by other pollutants or in other regions, nor has it been possible to reflect the impact of the general adjustments the economy would make to pollution control programs and the resulting reduction in damages.

Finally, with effective abatement, the estimate of benefits associated with a given level of pollution control can be expressed in terms of the corresponding reduction of damages. This step, in turn, requires the definition of a quantitative relationship between reduced emissions and resultant ambient levels, as well as between these improved ambient levels and reduced damages. Development of pollutant transport and dispersion models describing the first set of relationships has been only partly successful because of the many ill-defined variables involved. Thus, it is commonly assumed that the fractional decrease in ambient levels is essentially proportional to the fractional reduction of emissions. The second set of relationships is defined by the damage functions discussed earlier. The unit damages obtained from a damage curve are converted to total damages through multiplication by the number of units at risk and the cost-per-unit damage, as appropriate.

Thus, assessment of benefits associated with a given level of pollution control is still most assuredly an art, which permits divergent interpretation of available data that may lead to widely differing results. For this reason, although certain studies on air and water pollution damages are cited in Sections Two and Three, national aggregate damage estimates are not presented in this report.

Chapter 3
Pollution Control Cost Reduction Through Process Change

INTRODUCTION

Opportunities for air and water abatement cost reduction through process change were identified for 40 industries. Five industries were examined in detail: Copper, Aluminum, Pulp and Paper, Petroleum, and Inorganic Chemicals. Using Reference Case abatement costs developed in Sections Two and Three as a baseline, the extent of reduction achievable through specific process change candidates in each industry was determined. The relative savings in accumulated capital expenditures through 1985 in the five industries are: 14.5 percent, 9.6 percent, 10.1 percent, 12.0 percent, and 2.5 percent. The analogous savings in annualized costs for 1985 are: 35.0 percent, 11.0 percent, 28.5 percent, 24.0 percent, and 25.0 percent. When these savings are assessed in terms of their applicability to opportunities in the other 35 industries, the total capital and annualized cost reductions for all 40 industries relative to Reference Case abatement costs are estimated to be (in percentage reductions): 1.2 percent and 9.9 percent.

Impact of Process Change Upon the Cost of a Clean Environment

Pollution control legislation and associated effluent guidelines require that industry attain specific levels of pollutant control. The mechanism for achieving these levels is left to the discretion of each industry. The simple approach is to add treatment steps to the process at the points of waste emission, which are termed end-of-pipe control. The costs associated with these end-of-pipe (EOP) steps furnish an economic motive for waste-reduction process changes. If a net abatement cost reduction can be achieved through process change relative to that process or a competing process employing end-of-pipe treatment, an incentive for process change exists. This concept is evidenced in the generic types of process change in the more advanced standards (BAT, BPT, NSPS). For example, process changes designed to reduce water requirements, permit greater water reuse, and minimize leaks and spills are included in the compliance strategies recommended in the EPA effluent guideline development documents; considerable evidence exists to indicate such potential. Exemplary plants in many industries do operate at much higher efficiencies than the corresponding typical plants, and plant modernizations have been able to substantially improve abatement efficiency at a reasonable cost. In this discussion, emphasis is placed upon assessing the cost reductions achievable through process changes other than those included in the Reference Case of Section Four.

A number of important distinctions must be made. There are important differences between what can be achieved in a new plant as compared with the upgrading of an existing facility. In some instances, it is less costly to abandon an existing facility and build a new one than it is to convert the older facility. In such a case, nearly all capital associated with the abandoned plant must be forfeited. When conversion of the existing facility is reasonable, the capability to do so may be unevenly spread across the industry. The larger firms have both greater technological capability and financial reserves than the smaller firms. Thus, even a technologically-feasible retrofit process change may have considerable economic impact.

Such economic considerations are well known. They are restated here to emphasize their importance in assessing process change as a method of reducing end-of-pipe treatment requirements. A final general comment of this type pertains to tax considerations. If a tax benefit is granted EOP-type investment and not those related to process change, there is an incentive to pursue the former course.

This discussion identifies the type of savings that may be achieved through process change. The estimates made are intended to be indicative rather than exact; i.e., the analysis objective is to establish reasonable bounds between which the impact of process change can be evaluated. The reference cases for comparison are the industry costs established in Sections Two and Three of this report. The measure of the economic benefit from the process change is the extent to which the pollution control savings relative to the Reference Case exceed the costs incurred in the process change. The industry-wide savings are derived by identifying the extent of industry acceptance of the designated process change.

Effect of Environmental Standards on the Rate of Process Change

In considering the effect of environmental regulations on industry's acceptance of process change, it must be remembered that this relationship takes place within the framework of industry's overall investment decisions. Most industries have a tacitly expressed, minimum acceptable rate of return. Below this level, investment is not believed to enhance a company's financial position, and other considerations, such as liquidity, may predominate. Whether or not sufficiently lucrative opportunities exist often depends on the investment climate, which in turn may be heavily influenced by interest rates, current market behavior, etc. Even under favorable investment conditions, corporations have limited capital resources. Consequently, they must select among investment options, seeking the opportunity most likely to bring a high, reliable return on venture capital.

Comparison of investment opportunities is conducted on the basis of comparative profitability. A piece of equipment, like a furnace, will process a given product throughput over a specified lifetime. The value of this production, based on projected prices, is compared against the capital outlays required to build and operate the unit; ancillary costs and benefits must be included in this comparison. An existing furnace has an established set of operating specifications: energy requirements, recovery efficiency, etc. If the challenging process can reduce energy needs, the operating savings that result are included in the profitability comparison.

In addition, an attempt should be made to assess the "venture risk" involved in the investment; an example is a shoe manufacturer's investment in a line of ski boots. The investor understands that an unseasonally warm winter might cut his sales prospects in half. This estimate of risk is taken into account in determining the desirable rate of return. Venture risk similarly applies to the introduction of new processes, where the firm takes a risk that the process will not live up to expectations.

In a highly competitive market, the costs associated with end-of-pipe control may be so high that firms cannot pass them on as higher prices without losing competitiveness. These plants must either develop alternative control strategies that can be implemented at an acceptable level of cost, or close their doors. In these cases, in-plant controls can truly be said to be environmentally inspired.

However, environmental regulations can also indirectly affect investment decisions by altering the profitability of certain options. Existing facilities will have additional capital and operating costs associated with end-of-pipe treatment of its wastes, assuming compliance with environmental standards. In-plant changes that reduce treatment costs will be treated like any other benefit in profitability calculations.

Abatement costs can affect the process trends that would have developed in the absence of environmental considerations in a variety of ways. The additional cost can tip the scales in favor of a project that was formerly less profitable. Alternatively, it can further improve the profitability of an already preferred investment opportunity, thereby accelerating its rate of acceptance by the industry. It is important to realize that in both these events the environmental regulations are only one of several motivating factors; the abatement savings are not usually sufficient to justify investment unless other advantages are gained as well. This fact becomes relevant when allocating the portion of cost savings attributed to the environmental regulations.

On the other hand, environmental investments do involve one special circumstance that vitally increases their importance. Traditional decisions on an investment, such as capacity expansion, offer a firm three choices: expansion using proven technology, expansion using a challenging process, or no expansion. By law, abatement decisions do not permit the third path of inaction to be taken; either an alternative abatement strategy must be found, or the present plant abated through end-of-pipe methods. Furthermore, expenditures on equipment with the sole function of control yield no direct economic return to the corporations. Consequently, firms may be receptive to strategies that can attain abatement objectives while in some way improving the processing efficiency of the plant.

Before proceeding, two cases should be noted in which environmental regulations do not affect general process trends. The first case is where little difference exists between the abatement costs for the two processes. If a relatively new process is only marginally more profitable after subtracting venture risk than the established technology, most companies will retain the proven profit-maker. This is important in the present discussion because the time frame in which alternatives to EOP treatment can be undertaken is very short. In the second case, a process that has to pay much higher abatement costs may remain more profitable than its competitor. In this case, the "dirtier" process will continue to be substituted for the "cleaner" process. This process change will have the effect of increasing total industry abatement costs.

Types of Process Change

A survey was conducted within 29 polluting industries to identify those process changes that have significant pollution treatment implications. Three major categories of process change were found: material changes, process modification, and process substitutions. An additional and important type of change exists that, while not associated with a specific process, affects the control costs for each process. These are plant-wide changes, such as housekeeping, coordinated water usage by a set of processes to achieve a net reduction in water usage, etc. In the following discussion, plant-wide changes are addressed in terms of their effect on individual processes.

MATERIAL CHANGES

Material changes include modifying the nature or quality of raw materials employed or adjusting the specifications of the product produced. For example, use of natural Trona as a source of sodium carbonate obviates the large quantities of waste generated by Solvay process synthesis of sodium carbonate from salt and limestone. Likewise, use of rutile rather than ilmenite in the production of titanium dioxide significantly reduces waste quantities. Alternatively, synthetic rutile can be generated by pretreatment of ilmenite. Recycled or secondary material inputs are also important. For example, increased aluminum recycling circumvents the waste produced during bauxite processing. An example of a product specification change is the incorporation of a portion of process waste sludge in paper products not requiring high brightness.

Often, material changes are made on the basis of economic considerations related to materials availability. For example, domestic bauxite is of lower quality than bauxite imported from Jamaica, Surinam, or Australia; hence, the majority of bauxite consumed in the United States each year is imported. However, if the countries of origin are able to establish a higher bauxite price, the domestic alternative will appear more desirable. Such a change in material input will affect the nature and increase the quantity of wastes generated. Another example relates to the use of rutile in titanium dioxide production, as already discussed. Rutile, possessing a higher titania content, is predominantly imported from Australia, while large quantities of ilmenite ore exist in the United States. An adjustment could be made in the event rutile became either hard to obtain or highly priced. Again, the nature of the waste stream would change.

Crude oil quality also varies with its point of geographic origin. For example, Middle Eastern crudes have a higher sulfur content than domestic crudes, and the percentage usage of the former is increasing. Meanwhile, restrictions on the sulfur content of fuel oil for consumer use require that the refinery, which is now dealing with additional sulfur in its primary raw materials, reduce the sulfur content in its final product. This change in product specifications directly affects the amount of processing required, and, hence, the pollution-control related costs.

Environmental considerations are only one of the factors impinging upon the selection of raw material type. Nevertheless, the nature of the raw material utilized can have a direct effect upon the costs of pollution abatement.

PROCESS MODIFICATIONS

Three types of process modification were identified: revised process operation, byproduct recovery, and process-specific waste treatment.

1. Revised Process Operation. This category includes those process modifications made in an effort to improve process economics. The principal attribute is that in some way the efficency of the central reaction is improved, i.e., greater quantities of the desired products and lower quantities of pollution are generated per unit of input material. This may be accomplished by changing the temperature or pressure of the reaction, extending or shortening the residence time, improving reactant mixing, introducing a more stable catalyst, increasing recycle quantities, reducing water use, or invoking real-time computer control. In some cases, optimal process operation when pollution control is required will differ from that when such control is not required. Usually, a complex linear programming scheme is required to balance the many factors involved in identifying the optimal performance, and this determination is strongly affected by the character of the input materials, as previously discussed.

2. Byproduct Recovery. The recovery of a salable material from the process waste stream is an obvious and often mentioned method of simultaneously reducing the waste load and at least partially compensating for the costs involved. However, the opportunity to profitably sell such recovered materials is sometimes elusive. An extreme example is the recovery of sulfur and its

various compounds as pollution control. The marketplace may be unable to accommodate the quantities of sulfur to be made available. Hence, extraction of sulfur from the air and water waste stream could merely serve to transform the sulfur into a more readily-controlled solid waste. Attempts are underway to expand the market for sulfur compounds by identifying new applications, but there may be limits to the amount of market expansion possible.

In many cases, recovered material can be put to profitable use. Frequently, the application is an in-plant use of the recovered material to perform a function that previously required a purchased input, (e.g., heat and fiber reuse in the paper industry). In addition, industrial complexes are beginning to cooperate in using each other's waste streams when a desired attribute is present.

3. Process-Specific Treatment. This process modification is the treatment of process waste prior to merging it with the waste streams of other processes for end-of-pipe treatment. In general, the process waste must have some specific attribute that necessitates a unique treatment step; otherwise, the economies of scale associated with end-of-pipe treatment prevail.

Process Substitution. Process substitution is differentiated from process modification in that a fundamental change is made to the central reaction step. For example, going from the mercury cell to the diaphragm cell in chlorine production and from the open-hearth to the basic-oxygen furnace in steel production are process substitutions. For comparison, changing the reaction conditions, enlarging the reactor, or adding ancillary process equipment are process modifications.

Process substitutions are an extremely important process change category in terms of their effect upon pollution control requirements. A recent study of solid waste generation[1] showed that for 17 of the 34 largest producers of process solid waste among industrial chemicals, a process substitution was underway or had already taken place. In each case, the amount of solid waste generated was reduced. As process efficiencies are improved, the yield of the main product goes up and the quantity of waste generated correspondingly goes down. In addition, the remaining wastes tended to be easier to treat. Usually, wastes associated with the raw materials can be segregated with comparative ease. The ones produced during the principal reaction, however, are generally closely associated with the main product, and hence, are more difficult to separate.

COSTING METHODOLOGY

The Industry Survey analysis, which appears later in this discussion, disclosed a number of promising process change opportunities. These opportunities were evaluated to determine the extent to which such process changes can be expected to reduce pollution control costs relative to the Reference Case, primarily an end-of-pipe approach. To do this, five representative industries were selected that together illustrate the various modes of process change. Specific process change candidates, ranging from the modification of a single processing step to replacement of an entire process, were examined. For each challenging and defending process, total unit costs (process + end-of-pipe) were calculated. The capital requirements and annualized costs of the changed operation were compared with costs developed for the Reference Case discussed in Section Four.

Costing at the Unit Level

A new process may be related to existing operations in one of three ways:

1. It can be basically interchangeable with part of the existing plant, with potential for both retrofit and new plant applications. (Examples: Continuous and batch digesters, oxygen paper processes, flash and reverberatory furnaces.)

2. It can be basically incompatible with in-place facilities and represent an alternative for new capacity only. (Examples: Hydrometallurgy, dry forming of paper.)

3. It can be basically additive in nature, with no unit serving a comparable function in the present process scheme. (Examples: Byproduct recovery units, spill containment systems.)

Each of these relationships calls for a different type of comparison of basic process costs. Table 1 diagrammatically represents the basis for comparison in each of these situations.

Table 1.
Nature of Process Cost Comparisons

		Relevant Cost Parameters		
		Old Process	vs.	New Process
1. Inter-changeable Processes	Retrofit Application	O&M		Capital, O&M
	New Plant Application	Capital, O&M		Capital, O&M
2. Alternative Processes		Capital, O&M		Capital, O&M
3. Additive Processes		None		Capital, O&M

Values for capital, operation and maintenance (O&M) and annualized costs were obtained from available engineering cost estimates. Capital costs represent the installed costs of process equipment; this figure includes actual component costs plus expenditures for engineering plans, site preparation, and construction of necessary auxiliary facilities. Startup costs and penalties for plant shut-down time have not been included, because these values tend to be very plant specific. The operation and maintenance category includes: materials, taxes and insurance, direct and indirect labor, and maintenance. Annualized costs are defined as O&M costs plus depreciation on capital investment (calculated at 10 percent of the unpaid principal per year and normalized over the capital lifetime). All costs are developed for specific plant configurations, or model plants. Where competing units exhibit different economies of scale, more than one model size was used.

Sources of process cost estimates included technical journals, EPA economic impact studies, and other government publications, such as Bureau of Mines Information Circulars. The available materials frequently had to be converted to a form applicable to cost comparison at the unit level. In some cases, simplifying assumptions were employed. For example:

- Operation and maintenance figures are frequently available only at the plant level. In these instances, allocations between processes were constructed on the basis of information contained in the source literature. In the copper industry, for example, operating costs were provided for a typical smelter.[2] For some of the operating expense items, such as electric power, chemicals, etc., the significant in-plant users were delineated; costs could therefore be attributed to those specific sources. For materials where detailed information was not available, and for general expenditures (labor costs, maintenance), costs were distributed according to the fraction of total capital investment represented by each unit process.

- For some units, estimates of capital and O&M requirements are simply not available. This is particularly true for old defending process technologies, like the open-hearth steel furnace, where the last new unit of its type was built many years ago. Cost estimates for these processes were related directly to estimates obtained for challenging processes. The comparison between hydrotreating and drying and sweetening, included in the representative industry evaluation of petroleum refining, is a case in point. Operating costs for drying and sweetening can be expected to be lower than those attributed to a hydrotreating unit, due to the large hydrogen requirements of the latter process. Where operational differences could be clearly indicated in this manner, costs were estimated in accordance with these deviations; otherwise, costs were presumed to be roughly comparable.

End-of-Pipe Costs

The Reference Case for abatement costs is the set of costs provided for each industrial sector in Sections Two and Three of this report. These estimates were developed for current and projected plant inventories using treatment cost curves which are contained in Reference 3. This material was supplemented by information obtained from EPA development documents, technical and trade journals, and other recent studies on the costs of pollution control. To make this data base responsive to the specific needs of the process change investigation, methods had to be devised for the allocation of Reference Case costs between specific unit processes, and the translation of waste load reductions possible through process change into a revised estimate of end-of-pipe costs.

ALLOCATION OF REFERENCE CASE COSTS

Much of the information concerning abatement costs has been developed only at the plant level, while process changes frequently affect a single phase of the production process. Where this dichotomy exists, some technique for apportioning treatment costs among the processes within a plant is necessary. The demands on this allocation method increase with the complexity of the control problem.

In the simplest case, each piece of pollution control equipment in the treatment scheme can be associated with the abatement of a particular pollutant generated at a single source within the plant; e.g., a baghouse for control of particulates from process A, and a wet scrubber for control of sulfur oxide from process B. In this instance, the only information required for cost allocation is the breakdown of total abatement costs into the expenditures required for each control component.

More often, however, a pollutant is generated at a number of sources within a plant. In the case of copper smelting, sulfur oxide off-gases. are produced in various proportions during each of the major processing steps (roasting, furnacing, or conversion). Some, or all, of these streams may be combined and sent to the same treatment sequence. If a control device handles wastes from several plant sources, some portion of the related costs of control should be assigned to each of these process sources on the basis of the fraction of total pollutant loading each contributes. To calculate these fractions, emissions factors that establish a general ratio between pollution and output must be obtained for each relevant process. These factors, when multiplied by the model plant unit capacity, provide an estimate of plant waste loads. If roasting is found to contribute 55 percent of plant sulfur oxides, it is presumed that it can be assigned 55 percent of the reference case costs incurred in controlling that waste stream by means of a scrubber, acid plant, etc. This assumed one-to-one correspondence is not entirely accurate, due to the fact that wastes classified in the same general pollutant category (TSS, particulates) can have widely-divergent strengths and treatabilities. Nonetheless, the relationship is a generally accepted rule of thumb which has been employed in other recent abatement cost studies.[4]

In a single plant, many different types of pollutants are generated, and must be controlled by the same abatement facilities. Ideally, some portion of the total costs should be allocated to each of the pollutants removed by the treatment system. Formulas of this type have been developed for the inorganic and organic chemicals industry.[5] There were serious limitations, however, in the application of this type of analysis to the representative industry examples. Detailed breakdowns of model plant waste loads to the subprocess level are only available for a limited number of pollutants. Similarly, references on waste reductions resulting from process changes often confined their discussion to one or two major parameters. Consequently, it was frequently necessary to designate one pollutant as the dominant concern of industry abatement standards. In the petroleum industry, for example, BOD removal was concluded to be the compelling force behind BPT standards; costs for installation of the required biological treatment systems were therefore allocated between the various in-plant sources of that pollutant.

WASTE REDUCTIONS AND REVISED ABATEMENT COSTS

The relationship between the reduction in waste load and the reduction in treatment costs is not proportional. A 10 percent diminution of plant wastes might result in a 5, 8, or even 12 percent savings on control expenditures, depending on factors like the economies of scale involved, the degree to which control systems are modular, etc. Two approaches were utilized to determine the cost reduction associated with a given level of waste reduction. Where information estimating this relationship was provided in the literature, this material was employed. An example of this type of information is the study by McGovern[6] on waste reduction in the petroleum industry. In the absence of specific analysis, end-of-pipe cost savings were measured by moving down the treatment cost curves[7] to a facility size consistent with the waste load reduction achieved. The difference between this revised value and Reference Case costs represents the savings. After the revised level of end-of-pipe expenditures is determined, allocation of these costs among unit processes is again undertaken in the manner outlined above.

The example of substituting hydrotreating for drying and sweetening can be used as an illustration of these two procedures. A model plant configuration was chosen[8] which included drying and sweetening. Using BOD as a surrogate indicator, the contribution of this process to the total refinery waste burden was 45 percent. This fraction was then applied to the estimated total for plant end-of-pipe expenditures, to determine the costs attributable to drying and sweetening. For the same plant, waste loads were recalculated, utilizing lower polluting hydrotreating processes in place of drying and sweetening. The resulting reduction in waste (42 percent) was converted into its equivalent effect on end-of-pipe costs (23 percent), using materials generated by the McGovern study. The percentage of new total BOD coming from hydrotreating was calculated, with this fraction applied to the revised cost estimate.

Economic and Environmental Motivations for Process Change and the Allocation of Cost Effects

In addition to indicating the substitution potential of new processing concepts and the pollution control cost savings resulting from their implementation, the unit cost comparisons can serve as a basis for speculation about the motivating force behind a process change decision. In some cases, e.g., spill containment in the paper industry, process changes are adopted that provide no economic return on investment, the only benefit being a reduction in end-of-pipe costs. Changes of this type can truly be said to be environmentally inspired. Therefore, the costs for installing and operating the containment system should be charged to pollution control. Conversely, some concepts, like the Bayer-Alcoa aluminum process, have processing advantages that are sufficient to insure their adoption before end-of-pipe savings are taken into account. An approximate line of demarcation beyond which process changes are economically motivated is an industry's minimum acceptable rate of return. Since pollution control savings are incidental to the decision maker in cases providing greater rates of return, it is inappropriate to attribute these costs to pollution control.

In between these two clear cases lies a substantial gray area. Recovery and sale of byproduct H_2S and NH_3 in a large petroleum refinery* results in a return of about 3.6 percent a year; this profit margin would not in itself be sufficient to justify the investment. However, when environmental savings are included and the revised treatment system is contrasted with a pure end-of-pipe approach, the process becomes very desirable. It would be logical to charge only part of the process change costs to pollution control.

This concept, although important to recognize, can not be accurately implemented given the present data base. Minimum acceptable rates of return vary by several percentage points among companies in the same industry. A more detailed analysis of industry is required to delineate these variances. Similarly, there is a degree of inaccuracy in the estimations of process cost effects. Even a slight error can negate the accuracy of a carefully-constructed allocation algorithm. Since only a few of the changes examined in the representative industry studies lay in this gray area, none of the savings in basic process costs stemming from process change were included in the estimates of control cost reductions. It should be emphasized, however, that the resulting estimates represent the lower boundary of possible savings.

Costing at the Industry Level

Even though a particular process change may be shown to be economically profitable on the basis of the unit level comparison, the opportunities for its application may not be fully exploited. It is necessary to establish the industry context into which process change variables are introduced because certain characteristics of the industry environment will constrain or encourage adoption of new process ideas. Table 2 presents a partial representative list of elements in the contextual picture that were examined for their possible influence on the rate of penetration. These limiting factors can be physical or financial, and not all of these factors are applicable to each industry considered in the representative evaluations.

Table 2.
Some Factors Affecting Process Change Potential

	Factor Considered	Reason for Consideration
1.	Industry growth rate	Taken together, these estimations measure the amount of new capacity being built. If the process change being considered is an option for new plants only, the possibilities for penetration are highly controlled by these variables.
2.	Rate of plant obsolescence/ replacement	
3.	Availability of input materials (Ex. - higher grade ores, low sulfur fuels, rutile)	External (outside the industry) market conditions frequently constrain the ability of the industry to employ particular options. This is especially true of raw material changes and byproduct recovery and sale.
4.	Availability of markets for recovered byproducts.	
5.	Industry attitude toward process change	The historical receptiveness of the industry to new process ideas is a general indicator of the time frame required for the industry to implement new methods on a large scale.
6.	Size distribution of plants	The profitability of process change is frequently linked to economies of scale.
7.	In-place end-of-pipe abatement facilities	For a plant with an already installed treatment system capable of meeting environmental standards, the utility of installing process change measures designed to reduce waste load is greatly diminished.
8.	Availability of capital	If a particular process change requires a large initial capital investment, its application may be restricted to those firms with higher profit margins and favorable liquidity position.

Because the possibilities for process substitution in a given industry are dependent on the complex interactions of several variables, a scenario approach was utilized to indicate the range of possible results. Two basic scenarios were defined: a maximum, and a best-guess estimate of process change penetration. In the aluminum industry, for example, the best-guess market share for the Alcoa smelting process in 1985 is 8 percent of primary aluminum capacity; if maximum penetration is assumed, the share increases to 12 percent. The difference between these scenarios is the assumption of price or other constraints on the availability of bauxite and energy inputs. In some cases, the maximum and best-guess penetrations are equivalent.

For each alternative, pollution control costs as modified by process change were calculated and compared against the Reference Case estimates. To aggregate costs to the industry level, a size distribution of existing and future plants was estimated. The cost studies in Sections Two and Three of this report assign existing facilities in the plant inventory to various size classes. For future growth, plant capacities were developed from information on known expansion plans and extrapolation of recent size trends.

INDUSTRY SURVEY

This section summarizes the results of an industry survey to identify those process change opportunities having implications for pollution control costs. Each industry considered in the cost studies of Sections Two and Three in this report were assessed to determine the answers to two questions: Is the industry a significant contributor to air and water pollution, and are there opportunities for process change that can reduce the total cost of abatement? By comparing estimates of current industry effluent levels with corresponding national totals, a general measure of significance was developed. If an industry contributed more than 1 percent of the national total for any major pollutant parameter, it was considered to be a significant polluter. In the case of air emissions, this analysis was supplemented by comparing industry abatement costs to total abatement expenditures. Additionally, sectors were judged significant if they were responsible for highly toxic emissions (mercury, asbestos, etc.) that pose special abatement problems.

If the answer to the first questions was affirmative, the industry was further investigated for process change potential. Trade journals and other magazines, EPA development documents, previous Cost of Clean Air and Water reports, and other reports on the subject of industrial pollution control formed the base from which the survey results were developed. A process change was considered a viable alternative only if it had at least been tested at the pilot plant level.

The results of the industry survey are summarized in Table 3, with additional information provided in the industry profiles.[10] All process changes discussed in these profiles have been classified according to the type of process change involved, the media affected, and whether or not the change was included as part of the Reference Case abatement strategy.

Table 3.
Summary of Survey Results

Industry Category	Significant Polluter?[1]	Pollution Reduction Potential Through Process Change?
Fossil Fuels Group		
Coal Cleaning	---	---[3]
Natural Gas Processing	---	---
Petroleum Refining	A,W	W
Steam Electric Power	A,W	A
Foods Group		
Feedlots	W	W
Meat Products Processing	W	W
Dairy Products Processing	W	W
Seafood Processing	W	No
Canned & Frozen Fruits and Vegetables	W	W
Feed Mills	A	No
Grain Handling	A	No
Beet Sugar	W	No
Cane Sugar	W	No
Fertilizer/ Phosphates	---	---
Construction Materials Group		
Cement	A	No
Lime	---	---
Asphalt	A	No
Asbestos	A,W[2]	No
Insulation Fiberglass	---	---

Table 3. (Continued)
Summary of Survey Results

Industry Category	Significant Polluter?[1]	Pollution Reduction Potential Through Process Change?
Metals Group		
Aluminum	A,W	A,W
Copper	A	A
Iron and Steel	A,W	A,W
Lead	A[2]	No
Zinc	---	---
Other Non-Ferrous Metals	A,W[2]	No
Electroplating	W	W
Chemicals Group		
Inorganic Chemicals	A,W[2]	W
Organic Chemicals	W	No
Miscellaneous Chemicals	---	---
Plastics & Synthetics	W	No
Consumer Product Inputs Group		
Timber Products Processing	---	---
Pulp & Paper Mills	A,W	W
Builders Paper and Board Mills	---	---
Textiles	W	W
Soaps and Detergents	---	---
Leather Tanning	W	No

Table 3. (Continued)
Summary of Survey Results

Industry Category	Significant Polluter?[1]	Pollution Reduction Potential Through Process Change?
Consumer Product Inputs Group (con't)		
Glass	---	---
Rubber	---	---
Consumer and Government Services Group		
Dry Cleaning	A	A
Municipal		
Solid Waste Disposal	A	A
Sewage Systems	---	---

Key: A-Air; W-Water.

[1] Sectors are listed if they either pay more than 1% of total national abatement expenditures[11], or generate more than 1% of the national total of particulates, hydrocarbons, SO2, NOX, BOD, COD, TSS, or oils and greases.[12]

[2] Sectors generating highly toxic emissions.

[3] Sectors found to be nonsignificant polluters were not investigated further.

For several reasons, process ideas now being considered will not exert the same degree of influence over an industry's future planning. Some processes, though promising in theory, may encounter operational difficulties that substantially reduce currently anticipated economic benefits; other changes may be restricted in application to plants of a certain type, size, or age. Therefore, twenty-two "candidates" for further study were selected from the initial list of opportunities as best prospects for implementation within the time frame and at a level where they could seriously influence the abatement cost outlook for an industry. These changes are categories by type of process change and by industrial sector in Table 4.

Table 4, Sheet 1 of 3.
Process Change Opportunities by Industry and Type Change
A. Materials Changes

Industry	Raw Materials		Pretreatment		Product Specification	
	Old Process	New Process	Old Process	New Process	Old Process	New Process
Municipal Refuse Disposal						
Paper					High Brightness	Lower Brightness
Industrial Chemicals	Salt/Lime Ilmenite	Trona Rutile	Ilmenite	Synthetic Rutile		
Paints	Solvent Base	Powder Base				
Petroleum Refining					Downstream Control	Low Sulfur Fuel Oil
Iron and Steel			Released Fines	Pellet Agglomeration		
Copper	Sulfide Ores	Oxide Ores				
Aluminum	Bauxite High Grade Bauxite	Recycled Aluminum Low Grade Bauxite				
Electric Utilities			Stack Gas Scrubbing	Fuel Desulfurization		
Dry Cleaning						
Paper	Disposal	Sawdust for Pulping Fiber/Chem/Heat	Batch Digesting	Continuous Digesting		

Table 4, Sheet 2 of 3.
Process Change Opportunities by Industry and Type Change
B. Process Modifications

	Byproduct Recovery		Revised Process Operations	
Industry	Old Process	New Process	Old Process	New Process
Municipal Refuse Disposal				
Industrial Chemicals				
Paints				
Petroleum Refining	Disposal	Sulfur/NH_3	Barometric Condensers in Vac. Distillation	Surface Condensers
Iron and Steel				
Copper		Sulfuric Acid	Reverberatory Furnace	Flash/Electric Furnace/Hydrometallurgy
Aluminum				
Electroplating	Disposal	Chemicals Recycling		
Electric Utilities				
Dry Cleaning				
Textiles	Disposal	Recovery of grease from wool scouring/PVA Reclamation/Latex Recovery		Counterflow Washing
Fruits & Vegetables	Disposal	Solids Recovery	Once Through	Water Recycle

Table 4, Sheet 3 of 3.
Process Change Opportunities by Industry and Type Change
C. Process Substitutions

Industry	Old Process	New Process
Municipal Refuse Disposal	Incineration	Landfills/Minefills
Paper	Kraft Process Wet Forming	Dry Forming
Industrial Chemicals	Cl_2: Mercury Cell Na_2CO_3: Solvay Process TiO_2: Sulfate Process	Diaphragm Cell Trona Process, Chloride Process
Paints	Solvent Suspension	Electrostatic Suspension
Petroleum Refining	Catalytic Cracking	Hydrotreating Hydrocracking
Iron and Steel	Open-Hearth/Electric-Arc Blast Furnace	Basic-Oxygen Furnace, Direct Reduction
Copper		
Aluminum	Hall Process Bayer-Hall Process	Alcoa Process, Monochloride Process
Electroplating		
Electric Utilities		
Dry Cleaning	Petroleum Solvents	Synthetic Solvents
Textiles		
Fruits & Vegetables	Mechanical Peeling	Dry Caustic Peeling

At this point, five industries were selected for in-depth study: Copper, Aluminum, Pulp and Paper, Petroleum Refining, and Inorganic Chemicals. These industries were chosen because they were industries in which two or more process changes are concurrently being considered, and collectively, they contained examples of all the major types of process change. Additionally, it was felt that the data base of process change information in these areas was rich enough to permit detailed analysis. Short summaries of these representative evaluations are provided below.

REPRESENTATIVE INDUSTRY EVALUATIONS

Copper

The main environmental problem facing the copper industry is the control of sulfur dioxide contained in the off-gases from reverberatory furnaces used in primary smelting operations. Because of the very weak concentration of these gases (usually less than 1 percent sulfur dioxide by volume), they cannot be treated effectively through conversion into sulfuric acid. The costs of abatement are consequently very substantial; expenditures on control measures in a recent year, for example, represented 22 percent of total capital investment.[13] As a result, U.S. producers have greatly increased their interest in processing innovations that have the potential to reduce the industry's control burden. Research efforts have been directed in support of three main process alternatives: flash furnaces, electric furnaces, and hydrometallurgical smelting. The first American commercial scale example of each technology has either been installed within the past 5 years or is currently under construction.

PROCESS CHANGES

Flash smelting is a commercially proven technology that has been employed extensively in Europe and Japan for over a decade. Off-gases from the furnace attain sulfur dioxide concentrations of 10-14 percent and can be easily handled by an acid plant. By combining treatment of all plant emissions in a single facility, a 1,500-ton of concentrates per day smelter can achieve an estimated 11 percent reduction in capital requirements, and a 27.2 percent reduction in the annualized costs of pollution control. Although process costs for the flash furnace are somewhat higher due to additional slag processing requirements, overall unit costs figure to be 10-20 percent less than those estimated for a reverberatory furnace of comparable size. On this basis, it is projected that up to 50 percent of new pyrometallurgical capacity requirements in 1975-80, and 75 percent in 1981-85, will be supplied by flash smelters. If recently proposed new source performance standards[14] are promulgated which would specify more stringent and much more costly controls on reverberatory furnaces, the rate of penetration by the challenging technology will be further accelerated.

Electric furnaces claim a dual advantage over their reverberatory counterparts; they increase the sulfur dioxide concentration of off-gases by eliminating combustion gases within the furnace, and they exhibit a higher thermal efficiency. Two existing U.S. smelters have already made the switch to this technology as part of their abatement strategy. The smelting site must be close to a source of cheap electric power if the process is to be economically competitive. This fact alone will seriously restrict application of this technology in some of the remote and arid Western mining areas. In addition, industry spokesmen have frequently expressed doubts[15] about the operating reliability of electric furnaces. Consequently, the option is viewed as a less preferred alternative, with its substitution possibilities limited to areas where the cost of power is low enough to override other concerns.

Two hydrometallurgical smelting techniques, the Arbiter and Cy-Met processes, are in advanced stages of development. Major questions affecting evaluation of the substitution potential of these concepts concern the time frame in which successful scale-up can occur, and the extent to which current process cost estimates will accurately represent commercial scale results. If the operating economics achieved during pilot plant operations can be maintained, hydrometallurgy can reduce annual process costs by up to 25 percent; in addition, pollution control costs are practically zero, requiring only some form of storage or disposal for the sulfate solid waste which is produced. Even after successful scale-up, substitution will proceed slowly; hydrometallurgy will constitute no more than 4 percent total primary capacity by 1980, and 12 percent by 1985.

In addition to these basic process changes, it is necessary to assess the market opportunities for sale of the byproduct sulfuric acid generated during the control process. If there are profitable opportunities present, some of the estimated costs of pollution control can be defrayed; contrarily, if no opportunities exist, the costs of neutralization and disposal of the byproduct should be counted as an additional abatement expense. Competition for markets will be very strong, and smelter acids face one major disadvantage by being far from their primary users. However, smelters can take advantage of opportunities within the industry to use H_2SO_4 as a leaching agent to extract copper from oxide ores and mine tailings;[16] they can also increase their marketability by selling acid at a price well below the going market rate. Based on these parameters, four possible price/market opportunity scenarios were examined. In the combination of circumstances deemed most likely to occur, it was assumed that 12 of the primary smelters with acid plants will be able to sell their acid at an average price well below market rate, resulting in revenue of over $30 million per year.

INDUSTRY EFFECTS

The percentage reduction in pollution control costs resulting from implementation of the process changes discussed above is summarized in Table 5. The bulk of the savings attained through 1980 is the result of byproduct acid sales; the major increase in savings estimated for 1985 is attributable to greater application of flash and hydrometallurgical smelting technologies.

Table 5.
Copper Industry Abatement Cost
Reduction Through Process Change

	Percentage Change from Reference Case Abatement Costs (with Process Change)[1]	
	1980	1985
Cumulative Investment (from 1972)	-8.0%	-18.1%
Annual Costs	-15.6%	-26.5%

[1] From Scenario 2 - air control costs only.

Aluminum

The two pollutants of primary concern to the aluminum industry are red mud from the refining of bauxite, and fluorides from the reduction of alumina to aluminum. Red mud is usually impounded in an evaporation pond, and it is thus possible to achieve zero discharge.[17] Fluoride is associated with the Hall reduction process and is about 70 percent controlled to date. Existing facilities may have to install expensive secondary roof scrubbers to achieve the proposed standards of 90 percent capture.

A new source performance standard of 95.5 percent removal is achievable by the Alcoa Dry Scrubbing Process.[18] Other types of cells will require expensive secondary scrubbers. Thus, pollution control factors are prompting consideration of alternative technologies.

PROCESS CHANGES

Three process substitutions may have an effect on pollution control costs in the aluminum industry. The most direct factor would be an increase in the capacity to recycle scrap aluminum. Substitution of the Bayer-Alcoa[19] process for the Bayer-Hall would decrease the unit pollution control costs from primary smelting by 73 percent. Non-electrolytic processes, like the Monochloride[20] process would probably increase the unit cost of pollution control by 13 percent. Such a technology might be considered in the future because of energy and bauxite constraints.

INDUSTRY-WIDE COST REDUCTION

The penetration of new technologies is related to the growth rate of the industry, which in turn is related to the industry's pollution control cost. The absence of constraints on raw material availability or pollution output tends to preserve the present technology. Moderately-constrained growth tends to encourage the search for less-costly alternatives. However, for purposes of comparison, a 7 percent growth scenario with moderate penetration of recycling and the Bayer-Alcoa process is presented here.

The costs resulting from a Bayer-Hall/Bayer-Alcoa/recycling mix of 77 percent/1 percent/22 percent in 1980 and 68 percent/ 8 percent/24 percent mix in 1985 are shown in Table 6; note the lower capital and annualized operating figures for the process change case. The large increase in savings is due to the increased coverage of recycling and the Bayer-Alcoa process.

Table 6.
Aluminum Industry Abatement Cost Reduction Through Process Change

	Percentage Change from Reference Case Abatement Costs (with Process Change)[1]	
	1980	1985
Cumulative Investment (from 1972)	(-1.8%)	(-9.6%)
Annual Costs	(-9.0%)	(-9.0%)

[1] From Scenario 2 - air and water control costs.

Pulp and Paper Industry

The paper industry discharged 2.47 billion gallons of water in 1972, even though it was recycled over three times during processing.[21] About 60 percent of that water was used in direct process contact, higher than any other industrial activity. This leads to a discharge of about 2.2 million tons per year each of BOD and of suspended solids.[22] The industry spent 30 percent of its capital investment, the largest percentage of any manufacturing industry, in an effort to meet pollution control standards.[23]

PROCESS CHANGES

The pulp and paper industry has several short-term and several long-term water pollution control savings opportunities through process change. In the short-term (1975-1980), process modifications and product specifications changes can have a significant effect. Process modifications designed to contain spills, recover fiber, process chemical and energy have some savings involved. They range from a 20 percent savings per ton to a 65 percent savings per ton where applicable.[24] The increased use of lower brightness papers can result in a 67 percent saving in pollution control costs where applicable.[25]

Unfortunately, the applicability of these changes is limited to moderately old plants and the industrial tissue market, so that the overall savings potential is decreased.

The long-term (1980-1985) process substitutions of oxygen processes and dry forming, appear to have a substantial effect on the cost of pollution control.[26], [27] The use of oxygen for bleaching, waste treatment, and process liquor recovery result in a 53 percent savings in water pollution control costs. Dry forming of paper eliminates water pollution control costs where applicable. These process substitutions appear to have a wide range of applicability, but are limited to new capacity implementation.

INDUSTRY-WIDE COST REDUCTION

If it is assumed that 30 percent existing capacity and all of the new capacity before 1980 will take advantage of the near-term savings, and that 50 percent of new capacity after 1980 will take advantage of the long-term savings, the paper industry can achieve water pollution control costs savings as shown in Table 7.

Table 7.
Abatement Cost Reduction Through Process Change
Pulp and Paper Industry, Water Pollution Costs

	Percentage Change from Reference Case Abatement Costs (with Process Change)[1]	
	1980	1985
Cumulative Investment (from 1972)	(-7.4%)	(-14.4%)
Annualized Cost	(-17.6%)	(-27.4%)

[1] From Scenario 2 - water control costs only.

Petroleum Refining

The petroleum industry has made a number of in-plant improvements in the past designed to improve water effluent characteristics and increase water reuse and recycle rates. These efforts have been fruitful, with the water reuse ratio in the industry almost doubling in the last 20 years; nonetheless, refineries face substantial future outlays for pollution control systems. In-plant process changes designed to minimize end-of-pipe treatment requirements are likely to be a major part of the overall abatement strategy selected.

PROCESS CHANGES

Many proposed changes affect operations at the subprocess level, and can achieve substantial reductions in plant waste loadings for a fairly small initial capital outlay. An example of this type of process modification is the recovery of phenols produced during catalytic cracking. Removal of this pollutant can reduce total plant BOD by 7 percent and end of pipe costs by 5 percent. Additionally, there are economic advantages arising from the recovery of free oils entrained in the wastewaters from the cracker. Analysis of the effects of installing such a unit in three model refinery configurations[28], [29] indicates that this change could be profitable for a group of refineries comprising 65 percent of current total capacity.

Recovery of byproduct sulphur and ammonia from refinery sour waters has been a widely practiced technique in recent years, and is recommended in the EPA Development Document[30] as part of BPT abatement strategy. Analysis in this section of the study focused on estimation of the cost-offsetting benefits achievable through sales of recovered materials. Available process cost data on typical stripping and recovery facilities[31] demonstrates a potential for returns on investment of up to 20 percent per year, provided that all byproduct can be sold. For both sulphur and ammonia, a detailed analysis[32] was made of market conditions; and an assessment given of the competitive opportunities available to refinery producers. Results of this investigation indicated that sales of the ammonia and sulphur generated at current production levels could translate into revenues of $62 and $50 million, respectively, provided that maximum sour water recovery was practiced using dual stage stripping techniques. In addition, maximum processing resulted in 45 percent reductions in typical refinery BOD loadings, with a corresponding pollution control savings of 25 percent.

Greater use of hydrocracking has often been suggested as a way to reduce air and water pollution problems resulting from catalytic cracking operations. Although hydrocracking units offer greater operational flexibility and increased product yields in addition to reducing pollution problems, industry adoption of the process since its development in the 1960's has been very cautious. The major obstacle to implementation has been the higher costs associated with the challenging processes; this gap has recently widened due to sharp increases in hydrocracking input prices. As a result, a great deal of effort has been funneled into modification and improvement of the defending process. Major developments include use of new catalysts requiring less frequent regeneration, and the installation of carbon monoxide waste heat boilers. These recent events indicate a resurgence of expansion to catalytic cracking, with a resulting increase in end-of-pipe requirements and costs.

The use of hydroprocessing techniques has been rapidly increasing over the past decade, growing at an average of 8 percent per year. The addition of hydro-desulfurization steps to refinery operations reduces the waste burden of sulphur, nitrogen, and metals requiring end-of-pipe treatment, and concentrates these constitutents in sour water streams which can be readily processed for byproduct recovery. In other areas of refinery, hydrotreating processing can replace older, dirtier processes like acid treating, or drying and sweetening. Although the impetus for greater use of the processes is still strong, there are definite limitations on further extension of these processes in refineries which have already exhausted their in-plant hydrogen surplus, since hydrogen production facilities are an expensive capital cost item.[33] Further penetration by this process is likely to occur at a slower rate.

INDUSTRY-WIDE COST EFFECTS

It was very difficult to quantify the pollution cost savings possible in the petroleum refining sector. If all process changes discussed in this chapter were implemented in a specific refinery, waste load reductions of up to 60 percent could be achieved. There are many limitations restricting the substitution possibilities which exist; and, given the diverse structure of the industry, it was hard to determine the number of plants that were actually constrained. Nonetheless, it is believed that these various concepts could be introduced at a level sufficient to reduce average waste loadings of BOD by 20 percent. This corresponds to about 12 percent reduction in end-of-pipe capital and O&M costs. Additional revenue is added from byproduct recovery. Percentage estimates are summarized in Table 8.

Table 8.
Petroleum Refining Abatement Cost Reduction Through Process Change

	Percentage Change from Reference Case Abatement Costs (with Process Change)[1]	
	1980	1985
Cumulative Investment (from 1972)	(-12.0%)	(-12.0%)
Annual Costs	(37.3%)	(-33.4%)

[1] From Scenario 2 - water control costs only.

Inorganic Chemicals

Chemical and allied products rank first in industrial water consumption, with inorganics accounting for over one-fifth of this use.[34] The vast majority (72.3 percent) of water intake by inorganic chemicals is for cooling, with only 11.1 percent used as process water. The principal wastes are inorganic salts including chlorides, sulfates, carbonates, etc; other significant wastes include ore tailings and metals, such as chromium, mercury, lead and iron. In EPA's evaluation of water-borne pollution from 25 major inorganics, over 99 percent of the waste load was attributed to five products: sodium chloride (38.3 percent), sodium carbonate (35.6 percent), titanium dioxide (17.1 percent), and the coproducts chlorine/ sodium hydroxide (8.5 percent).[35] Each of these large waste products was evaluated for process change potential.

SODIUM CHLORIDE

Sodium chloride waste is usually deep-welled or stored, and does not pose a difficult water pollution problem.

SODIUM CARBONATE

There are two manufacturing processes for sodium carbonate (or soda ash). The older Solvay process synthesizes sodium carbonate from salt and limestone, with ammonia serving as a chemical intermediary. Approximately 1.5 kilograms of dissolved solid wastes are generated per kilogram of product.[36] The dissolved solids are about two-thirds calcium chloride, with the remainder mainly unreacted salt. The solids have slight market value and are usually discharged into surrounding water bodies. In contrast, the newer process utilizes natural ore, called Trona, or lake brines containing burkeite. Neither of these alternatives generates a troublesome waste, since ore tailings and brine wastes can be returned to the mine or lake.

The Solvay process has been steadily losing ground. No Solvay plants have been built since 1935. From 1960 to 1972 Solvay plan participation in soda ash production declined from 85 percent to 58 percent. The one advantage still held by the Solvay plants is geographic location. The Trona and lake brine deposits are concetrated in Wyoming and California, whereas market concentrations lie in the East. As a result, the natural ores have only gradually displaced the Solvay plants; pollution control requirements promise to speed this displacement. Partially due to such considerations, two Solvay plants closed between 1972 and 1974, further reducing process participation to 46 percent. The extent of Solvay process participation is the principal factor determining the aggregate water pollution control cost for sodium carbonate production. The anticipated closing of two of the smaller plants by 1977 will cut Solvay capacity by one-quarter, and reduce abatement capital and annualized costs by 28 percent (BPT and BAT costs are the same for this product).

Another important consideration is whether to recover a portion of the waste calcium chloride for byproduct sale. Assuming there is a sufficient market, recovery and sale of 20 percent of the calcium chloride would lead to an 81 percent reduction in annualized costs, but would necessitate a 206 percent increase in capital requirements.

TITANIUM DIOXIDE

There is competition both among processes and raw materials for the production of titanium dioxide. The older, sulfate process utilizes a more abundant, less pure ore, called ilmenite. Until recently, the newer chloride process has been restricted to the use of the purer rutile ore. Since the reserve of the latter is quite limited, 20 to 25 years at present consumption rates, raw material costs have played a large role in process selection. In spite of the rutile constraint, process efficiencies achieved with the chloride process have enabled it to increase its production share to 46 percent since its introduction in the mid-1950's. No new sulfate plants have been built since 1956.

Recent sharp increases in rutile and chlorine prices have tended to slow the encroachment of the chloride process. However, environmental considerations are lending a new competitive edge to the chloride process. The sulfate process generates 4 to 5 times the amount of waste per kilogram as compared with only 1.2 times for the chloride process.[37], [38] A significant aspect of the difference in waste load is the use of a purer raw material by the chloride process. The sulfate waste is mainly spent sulfuric acid and ferrous sulfate (copperas). The waste from the chloride process is primarily ferric chloride. Abatement capital requirements for the chloride process are only 56 percent of those for the sulfate process for BPT, and 65 percent for BAT. Similarly, annualized costs for the chloride process are 40 percent of those for the sulfate process for BPT, and 59 percent for BAT.[39]

Byproduct recovery is an important aspect of the pollution control opportunities for titanium dioxide. Ferric chloride from the chloride process is already being recovered and sold for water treatment by some companies, and can alternatively be converted to chlorine for recycling and to iron oxide for sale. Sulfate process waste acid can either be recovered and recycled or converted to gypsum, and then sold. Acid recovery and recycle in the sulfate process alone enables a 22.4 percent reduction in the total titanium dioxide accumulated capital expenditures for abatement through 1985, and a 23.2 percent reduction in annualized abatement costs in 1985.

CHLORINE

Environmental considerations have acted to reverse an ongoing shift among process alternatives for chlorine production. Worldwide usage of the mercury cell electrolysis process for chlorine substantially exceeds that of the competing diaphragm cell; in the United States, the latter has always been predominant. Nevertheless, mercury cell participation in U.S. chlorine manufacture had been on the rise, increasing from 4.3 percent of production in 1946 to 28.6 percent in 1968. At that point, concern regarding mercury emissions to the environment surfaced. Since then, some existing plants have converted from mercury cells to diaphragm cells, and little new mercury cell capacity is being added. By 1973, mercury cell participation had declined to 24.6.[40]

The wastes from the mercury and diaphragm cells are similar: brine impurities, unreacted salt, weak caustic, waste sulfuric acid, sodium hydrochlorate and sodium bicarbonate. However, the mercury cell waste also contains a limited quantity of mercury. The need for strict control of the mercury content causes significant abatement cost differences between the two cell-types. The diaphragm cell abatement capital requirements for BPT and BAT are only 13 percent and 36.4 percent, respectively, of those for the mercury cell. Likewise, the annualized capital cost comparison is 25.7 percent and 44.9 percent for BPT and BAT.[41] As a result, the ongoing shift from the mercury cell, if no new mercury cell plants are built, will reduce the accumulated capital expenditures through 1985 by 16.4 percent, relative to the Reference Case, and 1985 annualized costs for pollution control by 12.8 percent. It should be noted that a great deal of developmental work is underway to bring mercury cell control costs into line with those of the diaphragm cell.

INDUSTRY-WIDE COST REDUCTION

The industry-wide implications of the process change opportunities for the four chemicals, sodium carbonate, titanium dioxide, and chlorine/caustic, are presented in Table 9. The four chemicals account for more than half the abatement capital and annualized cost requirements for the entire industry. Presuming other chemicals have similar process change opportunities, a 38.1 percent reduction in abatement annualized costs in 1980 can be achieved and a 25.0 percent reduction in 1985. A slight (2.5 percent) reduction can be made in cumulative capital expenditures.

Table 9.
Inorganic Chemicals Abatement Cost Reduction Through Process Change

	Percentage Change from Reference Case Abatement Costs (with Process Change)[1]	
	1980	1985
Cumulative Investment (from 1972)	(0%)	(-2.5%)
Annual Costs	(-38.1%)	(-25.0%)

[1] From Scenario 2 - water control costs only.

GENERALIZATIONS

Range of Pollution Control Savings

The range of pollution control savings through process modifications varies among industry and category types of process change. This variation is to be expected if one considers the specific implementation limits on any given process change. Financial, technical, and physical constraints to process change vary considerably between industries and within each industry. The highly-specific nature of process changes and the varied nature of the industrial climate in which they are imbedded inhibits generalization.

Substantial savings have been demonstrated in the representative industry studies. These savings vary considerably from industry to industry as shown in Table 10. On the capital side, they range from a savings of 2.5 percent in inorganics to 14.5 percent in copper. The annualized savings are somewhat larger than capital savings, ranging from 11 percent in the aluminum industry to 30 percent in the petroleum industry. The advantages accrued through process change within the representative industry studies may serve as an indication of the range of potential savings in a similar situation in another industry. It is worthwhile to emphasize the approximative nature of the following generalizations; they are made to facilitate estimation of the overall effects of process change, and they do not represent precise assessments of the situation in a given industry.

Table 10.
Abatement Cost Impact of Process Change - 1985
(% Change from Reference Case: Cumulative Capital/Annualized Cost)

Process Change / Industry (Media)	Copper (Air)	Aluminum (Air/Water)	Pulp & Paper (Water)	Petroleum (Water)	Inorganics (Water)
• Materials Change	--	-3.2/-3.3	-0.1/-0.3	--	-2.2/-2.1
Raw Materials	--	Recycling	--	--	Trona (Na_2CO_3) Rutile (TiO_2)
Product Specification	--	--	Reduced brightness	--	--
• Process Modification	0/-21.8	--	-5.0/-21.5	-7.0/-25.0	+13.9/-9.9
Revised Operations	--	--	Spill Containment	Phenol Recycle	--
Byproduct Recovery	Sulfuric Acid	--	Fiber/Chem/Heat	Sulfur/Ammon	Calcium chloride (Na_2CO_3) Sulfuric acid (TiO_2)
• Process Substitution	-14.5/-13.1	-6.3/-7.7	-5.0/-7.0	-5.0/-5.0	-14.2/-13.0
	Hydrometallurgy/flash furnace/electric furnace	Alcoa	Oxygen processing	Hydrotreating	Chloride process (TiO_2)
		Monochloride	Dry Forming	Hydrocracking	Diaphragm Cell (Cl_2)
Industry Totals[1]	-14.5/-34.9	-9.5/-11.0	-10.1/-28.8	-12.0/-30.0	-2.5/-25.0

[1] Mean 9.72/25.9

Section Two

THE ECONOMICS OF AIR POLLUTION CONTROL

Chapter 1
Summary

The purpose of setting the ambient and emission standards associated with the Clean Air Act Amendments of 1970 (henceforth referred to as the Clean Air Act) is to protect human health and reduce or prevent the other damages associated with polluted air. To accomplish these goals, the emissions released to the environment must be reduced far below their 1971 levels.

The estimated net emissions of the five criteria air pollutants in 1971, 1975, and 1985 are shown in Table 1. Also shown in the table are the control efficiencies by pollutant for the three years. Note that particulates were controlled to a large extent even in 1971; quite often these controls existed for economic reasons. That is, plants recovered economically-valuable metals and materials from the particulate wastes.

Table 1.
National Trend in Emission Levels

Sources and Pollutants	Net Emissions[1] (Millions MT)			Control[2] Efficiency (%)		
	1971	1975	1985	1971	1975	1985
All Sources						
Particulates	31.6	16.8	5.9	64.9	85.0	95.6
Sulfur Oxides	30.0	22.8	18.6	25.4	51.9	71.2
Nitrogen Oxides	16.3	17.6	29.5	0	1.4	3.0
Hydrocarbons	14.3	10.5	7.0			55.0
Carbon Monoxide	71.2	55.1	28.7	9.9	16.8	20.0
Industrial & Electrical Generation						
Particulates	31.0	16.1	4.8	65.5	85.7	96.2
Sulfur Oxides	29.3	22.3	17.7	25.8	59.4	72.0
Nitrogen Oxides	7.8	9.3	14.2	0.2	3.6	5.7
Hydrocarbons	5.2	4.2	3.5	36.3	53.5	70.9
Carbon Monoxide	10.4	7.0	6.5	43.0	66.1	76.2

[1] Emissions after control devices have been installed.
[2] Percent of unabated emissions that are eliminated by the control devices.

In order to bring about these reductions in air emissions, businesses and consumers must make expenditures to install pollution control devices, institute process changes switch fuels, and operate and maintain these devices. Governments must allocate expenditures to regulate and monitor pollution sources, control their own emissions, and perform research.

Table 2 shows the estimated total expenditures for air pollution control brought about by the Clean Air Act during the 1971-85 period. Detailed information on standards and compliance schedule assumptions are presented throughout the remainder of this section of the report.

Table 2.
Accumulated Estimated Air Pollution Expenditures

(In Billions of 1975 Dollars)

	1971-1985 Total Costs	1976-1985 Total Costs
Industries	143.1	134.3
Transportation[1]	93.1	75.7
Government	5.1	5.1
Totals	236.6	215.1

Note: Government costs for the period 1971-1975 were not estimates.

[1] Mainly the costs for automobile emission controls that are paid for directly by the car owners.

The pattern that expenditures will take during the 1971-85 period depends not only on regulations, but also on the pattern of compliance by businesses, automobile users, and local governments. If compliance with present Federal regulations is assumed, the time path of expenditures during the 1971-85 period is shown by the Legislated Timing line in Figure 1; note the peaking of investment expenditures in 1975.

Figure 1.
Air Pollution Abatement Investment Costs by Industrial Sources other than Electric Utilities

Surveys by the Bureau of Economic Analysis in the Department of Commerce do not indicate such high past and planned investment on the part of businesses during the 1971-75 period. Therefore, some more extended pattern of expenditures will probably occur. The timing of air pollution expenditures made by EPA and CEQ in the 1975 report entitled The Economic Impact of Pollution Control: Macroeconomic and Industry Report's March 1975, prepared by Chase Econometric Associates, Inc., is assumed for this report. The dark lines on Figure 1 show the more probable expenditure pattern.

GOVERNMENT EXPENDITURES

The air pollution abatement expenditures related to P. L. 91-604 made by governments at all levels are shown in Table 3. Federal expenditures include those for state and local program assistance, research, abatement control, manpower development, and control of pollution from Federal facilities. The future estimates for expenditures by state and local governments include the functional areas of enforcement, engineering services, technical services, and management.

Table 3.
Government Spending for Air Pollution Control, 1976-85.

(In Billions of 1975 Dollars)

Year	EPA	Other Federal	State Local	Total
1976	112	186	120	418
1976T	28	46	30	104
1977	147	209	140	496
1978	152	209	140	501
1979	152	209	150	510
1980	152	209	150	510
1981	152	209	150	510
1982	152	209	150	510
1983	152	209	150	510
1984	152	209	150	510
1985	152	209	150	510
				5,089

TRANSPORTATION EXPENDITURES

Two major types of transportation control costs were estimated:

- Costs needed to meet Federal emissions standards for autos, trucks, and aircraft.

- Costs that residents of certain cities must pay to finance programs that will reduce transportation-generated emissions to achieve Federal ambient standards.

In this report, the former costs are mobile source costs and the latter are treated as Transportation Control Plan (TCP) costs. Table 4 shows these costs in summary fashion for the appropriate years. As is evident from the table, the TCP costs are very small in comparison with the total mobile source controls. The interrelationship between the two control strategies is complex; as emissions from individual vehicles are reduced, the relative impact of the transportation controls is also reduced.

Table 4.
Transportation Control Costs[1]

(In Billions of 1975 Dollars)

	Mobile Source Costs			TCP	Total Yearly
Year	Investment	O&M	Total	Costs	Costs
1968	0.09	0.48	0.57	-	0.57
1969	0.09	0.80	0.89	-	0.89
1970	0.49	0.86	1.35	-	1.35
1971	0.58	1.20	1.78	-	1.78
1972	0.55	1.51	2.06	-	2.06
1973	1.48	1.98	3.46	-	3.46
1974	1.08	2.42	3.50	-	3.50
1975	1.99	1.78	3.77	-	3.77
1976	2.68	1.19	3.87	0.34	4.21
1977	2.81	1.53	4.34	0.44	4.78
1978	2.50	1.81	4.31	0.32	4.63
1979	2.71	2.04	4.75	0.34	5.09
1980	4.19	2.50	6.69	0.35	7.04
1981	6.12	2.77	8.89	0.37	9.26
1982	6.07	3.15	9.22	0.40	9.62
1983	6.12	3.44	9.56	0.39	9.95
1984	6.22	3.79	10.01	0.40	10.41
1985	6.00	4.30	10.30	0.41	10.71
1968-85 Totals	51.77	37.55	89.32	3.76	93.08
1976-85 Totals	45.42	26.52	71.94	3.76	75.7

[1] Interest was not applied to investment.

INDUSTRIAL EXPENDITURES

Costs for industries to comply with Federal emission standards (for new plants or facilities in specially-designated industries) and State Implementation Plans (SIP) required to meet Federal ambient air standards were estimated for over 40 separate industries, such as Iron and Steel manufacture, Petroleum Refining, and Kraft Paper production. Table 5 shows the estimated expenditures for aggregations of these industrial sectors.

Table 5.
Industrial Air Pollution Control Expenditures
(In Millions of 1975 Dollars)

	1971-85		Accumulated Expenditures		1976-85	
Industry	Investment	Annualized Capital	O&M	Investment	Annualized Capital	O&M
Coal Cleaning	27.84	33.82	15.90	13.56	30.13	14.07
Coal Gasification	120.32	68.19	53.05	120.32	68.19	53.05
Natural Gas Processing	149.12	209.73	279.06	51.38	180.10	242.84
Feed Mills	2,027.08	2,737.18	1,058.76	941.70	2,411.26	936.91
Kraft Pulp Mills	2,342.13	3,542.82	4,253.08	1,313.41	3,117.88	3,801.29
NSSC Mills	313.44	431.00	581.12	130.10	367.73	517.44
Printing	44.03	68.71	57.67	21.51	60.14	51.22
Chlor-Alkali Mercury Cell	23.21	48.60	56.38	12.09	42.38	49.85
Nitric Acid	80.23	119.79	180.31	37.16	105.54	162.15
Paint Manufacture	34.47	59.99	77.95	11.88	51.73	67.64
Phosphate Fertilizer	175.14	212.04	358.47	97.40	188.31	323.69
Nonfertilizer Phosphate	10.60	16.22	6.07	5.66	14.47	5.42
Sulfuric Acid	721.90	1,200.52	718.77	247.89	1,036.32	636.97
Petrochemicals	48.51	55.33	472.84	25.90	48.93	422.80
Petroleum[1]				1,330.00	3,025.00	3,250.00
Ferroalloy	339.28	598.49	154.22	117.14	519.02	135.25
Iron & Steel[1]				3,300.00	13,250.00	3,870.00
Iron Foundaries	509.66	867.16	1,732.07	188.48	749.08	1,509.01
Steel Foundaries	269.23	538.46	45.33	18.72	428.26	40.34
Primary Aluminum	2,504.64	3,110.06	4,185.23	699.06	2,734.70	3,552.03
Secondary Aluminum	35.64	48.23	55.16	11.83	49.26	49.26
Primary Copper	1,210.84	2,103.11	1,309.19	378.67	1,817.81	1,136.63
Secondary Brass & Bronze	21.67	29.70	48.33	6.29	25.58	41.94
Primary Lead	47.50	80.05	45.19	13.56	68.78	38.48
Secondary Lead	6.33	8.77	.15.16	4.57	8.29	13.33
Primary Zinc	64.49	145.36	124.13	42.80	137.70	107.62
Secondary Zinc	2.52	3.15	7.30	1.32	2.78	6.41
Asbestos	768.42	1,669.03	48.85	3.35	1,287.70	39.18
Asphalt Concrete	664.19	1,181.97	2,029.12	161.49	1,011.30	1,771.61

Table 5.
Industrial Air Pollution Control Expenditures
(In Millions of 1975 Dollars)

	1971-85			Accumulated Expenditures	1976-85	
Industry	Investment	Annualized Capital	O&M	Investment	Annualized Capital	O&M
Cement	940.18	1,287.97	1,363.63	328.94	1,130.48	1,205.45
Lime Manufacture	330.01	474.83	111.59	110.27	405.24	98.53
Clay Construction Products	80.85	148.65	194.49	17.63	126.73	157.57
Surface Coatings	514.40	870.16	3,228.31	217.72	742.17	2,890.89
Steam Electric Power Plants[1]				18,160.00	24,650.00	18,700.00
Solid Waste Disposal	1,948.38	3,046.92	4,658.43	634.68	2,602.15	4,098.26
Sewage Sludge Incineration	186.30	228.60	153.42	111.40	204.30	141.86
Grain Handling	2,978.52	3,269.14	397.49	1,205.35	2,962.16	354.58
Dry Cleaning	242.65	346.39	0	80.44	302.74	0
Commercial Heating	3,756.23	4,148.98	7,556.87	1,737.49	3,637.61	6,647.87
Industrial Heating	11,012.19	14,924.53	5,446.88	5,006.32	13,124.39	4,850.12
Totals				36,917.00	82,725.00	61,900.00

[1] Figures based upon detailed independent studies of these industries which were recently completed for EPA by various consultants, as described in the industry summaries.

COMPARISON OF COST ESTIMATES TO THE LAST COST OF CLEAN AIR REPORT

For those industries analyzed in both reports, Table 6 presents a comparison of cost estimates, in as nearly comparable terms as possible. The last Cost of Clean Air Report (COCA) stated costs in fiscal years, whereas, this report deals with years on a calendar basis. The estimates from COCA were inflated to 1975 dollars in this listing. Several more industries have been included in this study, and are therefore not listed in Table 6.

Table 6.
Cost of Air Pollution Abatement
(Millions of 1975 Dollars)

	COCA (FY71-FY79)		SEAS (1972-1979)	
	Investment	O&M	Investment	O&M
Aluminum	1,278.9	280.5	2,070.3	1,063.8
Primary	1,256.6	276.6	2,040.2	1,052.8
Secondary	22.3	3.9	30.1	11.0
Asbestos	13.6	2.8	15.0	11.6
Coal Cleaning	18.9	1.8	27.3	3.5
Copper-Primary	589.2	75.6	1,177.5	278.2
Dry Cleaning	172.8	-	130.3	-
Feed Mills	1,652.4	88.8	1,804.4	222.5
Grain Handling	1,182.0	24.0	2,134.6	85.7
Lead	45.8	4.2	46.7	12.5
Primary	32.8	2.9	42.1	9.4
Secondary	13.0	1.3	4.6	3.1
Lime Manufacture	73.2	7.0	320.0	24.1
Natural Gas Processing	108.0	20.0	135.1	62.2
Nitric Acid	42.5	10.4	66.4	34.9
Phosphate Fertilizer	23.2	8.2	8.8	1.2
Portland Cement	532.8	95.8	883.8	293.6
Pulp & Paper	312.8	69.2	2,800.4	988.9
Kraft	280.8	58.8	2,540.5	869.9
NSSC	32.0	10.4	259.9	118.9
Sewage Sludge Incineration	75.2	8.7	212.8	25.9
Sulfuric Acid	488.6	51.5	686.9	150.3
Zinc	41.4	4.0	56.4	29.2
Primary	38.9	3.5	54.2	27.7
Secondary	2.5	0.5	2.2	1.5

As can be noted, many of the cost figures are higher in this report, as compared to the last Cost of Clean Air Report. Several factors account for this fact. The costing parameters for investment and O&M were inflated from a base year to 1975 using factors on an industry-by-industry basis. When these were used in the SEAS model, resultant figures were often higher than would have been the case using a data base similar to the one used for the COCA report. The growth factors generated by the SEAS model were often different than that assumed by COCA, and the time phasing pattern of investments was adjusted in SEAS to be uniform across the air abatement industries.

Another factor accounting for differences in the estimates is due to the inclusion of feedback effects of abatement-related purchases to the sectors that produce and sell those goods in the national economic forecasting model of SEAS. These feedbacks include direct impacts on the demand for abatement equipment and materials from supplying industries, as well as on abatement-related employment for operation and maintenance activities in the industries making the expenditures. A discussion of this methodology is included in Section 4.

Aluminum figures are higher because of revised judgments of industry capacity and control technology requirements, combined with the SEAS generated growth forecasts. Asbestos investment figures are within the +30 percent assumed on the cost functions. Model plant definition and industry forecasts played an important role in the Coal Cleaning differences in coal figures. The O&M figures assume a rapid increase in power requirements with size. Copper estimates are different due to the fact that previous cost figures were developed on a plant-by-plant basis, while SEAS uses model plants. This combined with the fact that SEAS assumes all growth in the industry has associated pollution control costs yielded higher results. There was also a re-definition in the parts of the industry studied.

Dry Cleaning forecasts from SEAS assumed 55 percent using synthetic solvents and the rest utilizing petroleum solvents for existing plants. New plants use only synthetic solvents with adsorption units. Several other costing assumptions affected the forecast. Feed Mills figures are different largely due to growth assumptions of SEAS, as well as plant size distribution parameters. Cost curves were developed on an industry-wide basis.

Grain Handling costs were based upon several assumptions, since precise estimates of investment and operating costs cannot yet be made, due to lack of data. Capital cost curves were derived from estimated throughputs of 1 million and 15 million bushels per year. The total capital cost is the sum of the weighted capital costs for the existing fabric filters, replacement of the cyclones, and installation on the plants with no controls.

The overall Lead investment costs are very close for both studies. However, the breakout of primary and secondary lead costs is different. This is largely due to different assumptions on growth patterns.

Lime manufacture has substantially revised costs. This is largely attributable to higher costs associated with bigger plants. The industry trend has been towards consolidation. The actual number of plants actually declined from 195 in 1970 to 186 in 1972, but there is an increased growth in production. SEAS does not assume any plant closings after the base year, and associates all growth with expansion in the number of plants. The combined effects have substantially altered the forecast.

Natural Gas Processing plants have an investment figure slightly higher in this report due to the combined effect of model plant class definition with associated cost curve estimates, and general growth patterns.

Nitric Acid cost curves have a high margin of error due to lack of data availability. For a particular model plant class, the associated cost may be substantially at variance with actual costs, due to technology assumptions, and the extent of applicability of NOx abatement in the industries. A true estimate can be achieved only on a plant-by-plant basis. For simplification, an assumption was made that controls for NOx abatement are employed by 15 percent of the industry capacity in all model plant categories.

Portland Cement costs are substantially higher in this report, due in large part to production forecasts and associated growth rates forecast by SEAS. There are several problems in estimating costs including a recent shift toward increased size of operations through installation of larger kilns.

COCA estimates for Pulp and Paper were extremely low. This report developed detailed model plant data and associated cost curves for both Kraft Paper and NSSC, with individual costs forecast by type of technology or process within the entire system of production. Control technologies were assumed to be the Oregon-Washington SIP's.

Cost data for Sewage Sludge Incineration forecasts was updated from the last COCA report, and, as such, substantially revised. Assumptions concerning growth patterns of the industry also affected forecasts.

Pollution control expenditures for the Sulfuric Acid industry are higher in this study, due to the growth pattern of demand for sulfuric acid. This may not actually increase the size of the industry, as SEAS would assume, because of byproduct recovery from other industries. The future growth pattern of this industry is uncertain.

The zinc industry forecasts for the two reports are based upon different segments of the industry, as well as the fact that SEAS includes expansion costs in its estimate.

Chapter 2
Benefits of Controlling Air Pollution

Contemporary damage estimates are based on the interpretation of the results of numerous studies of varying scope, methodology, and data quality. Dose-response data are most available for effects of sulfur oxides, oxidants, and particulates in the damage categories of human health and vegetation. Because of the high cost of obtaining statistically valid data on actual environmental damages, much of current pollution effects information is based upon extrapolation of data from controlled laboratory experiments.

In combining estimates from different classes of damages, care must be taken to minimize duplicate counts. For example, studies of the differences in residential property values associated with differences in air pollution reflect primarily the aesthetic and soiling effects rather than health, materials, and vegetation effects. This approach is based on the argument that the aesthetic effects are experienced directly in everyday life, whereas health effects are mostly long-term, and are not distinquishable by the general population from other causes of illness.

HEALTH DAMAGES

Nature and Effects of Air Pollution Damage to Health

The major air pollutants that have been linked to health damages are suspended particulates, sulfur oxides, nitrogen oxides, oxidants, and carbon monoxide. The effects of these pollutants are increased morbidity (incidence and prevalence of disease) and mortality. The specific diseases that have been associated with air pollution are bronchitis, emphysema, asthma, respiratory infections, heart disease, cancer of the respiratory and digestive tracts, and chronic nephritis. The quantitative relationships between these diseases and air pollutants have been explored in a variety of studies; other studies have examined the link between air pollution and measures of illness or discomfort, such as absenteeism, emergency ward visits, and automobile accidents.

The most widely-cited studies of the health effects from air pollution were performed by Lave and Seskin (1970, 1973) and by EPA's Community Health and Environmental Surveillance

System (CHESS). Lave and Seskin analyzed the relationship between mortality (in total and in 14 disease categories), a variety of socioeconomic variables, and several indices of suspended particulates and sulfates in the air. Their findings indicate that at least 9 percent of the 1960 death rate was attributable to particulates and sulfates. The strongest effects were on bronchitis and lung cancer.

The CHESS studies (1974) gathered data on a number of communities chosen to control socio-economic variables related to disease. A variety of indicators of illnesses were examined for their relationship to the pollution composite of sulfur dioxide, suspended sulfates, and total suspended particulates. The morbidity measures chosen as most significant were: asthma attacks, restricted activity days, and physician visits resulting from acute lower respiratory disease; prevalence of chronic bronchitis; and aggravation of cardiopulmonary symptoms in the elderly.

In a recent study, Sprey and Takacs (1974) indicated the likelihood that the health effects of air pollution may turn out to be greater than expected from previous studies. In this study, a greater range of specific pollutants and health effects was examined. Strong correlations were found between nitrogen dioxide and mortality from arteriosclerotic and hypertensive heart disease, cancer of the lung, larynx, and esophagus, and nephritis. In addition, sulfates were found to be associated with arteriosclerotic heart disease and cancer of the respiratory and gastrointestinal tracts. These results suggest that the fraction of the death rate associated with air pollution may be as high as 15 percent.

Survey of Source Studies

The majority of health studies center around damages from particulates and sulfur oxides. Recently, oxidants and carbon monoxide have been receiving increasing attention, but the data base is still very small for most important effects. Very little work has been done on nitrogen dioxide because of the difficulties in isolating the pollutant in ambient situations and problems in defining valid measurement techniques. The more important studies are listed in Table 1.

Table 1.
Summary of Health Effects Studies

Study	Publication Date	Location	Pollutants Measured	Effects
CHESS	1974	5 Areas	Sulfur dioxide, sulfates	Increased incidence of chronic and acute respiratory disease
Lave and Seskin		117 SMSAs	Particulates, sulfates	Mortality
Buechley	1973	New York-N.J.	Sulfur dioxide	Mortality
Finklea et al.	1975	Based on various studies	Sulfates	Mortality and various morbidity measures
Bates	1973	Laboratory	Ozone	Changes in lung function
Gardner	1971	Laboratory	Ozone	Stability changes in alveolar macrophages
Hazucha	1973	Laboratory	Ozone	
Zelac et al.	1971	Laboratory	Ozone	Chromosomal changes
Shoettlin & Landau	1961	Los Angeles	Oxidants	Aggravation of asthma
CARB	1975		Oxidants	Changes in respiratory function and susceptibility
Aronow and Isbell	1973	Laboratory	Carbon monoxide	Earlier onset of angina pain
Horwath et al.	1971	Laboratory	Carbon monoxide	
Beard and Wertheim	1967	Laboratory	Carbon monoxide	Time discrimination deterioration
Hexter & Goldsmith	1971	Los Angeles	Carbon monoxide	Mortality
Shy et al.	1970	Chattanooga	Nitrogen dioxide	Increased incidence of respiratory disease

A recent survey of health damage studies was accomplished by the National Academy of Sciences and the National Academy of Engineering (1974) in their report, Air Quality and Automobile Emission Control (1974), which concentrates largely on effects of carbon monoxide, with other pollutants treated in slightly less detail. Neuberger and Radford (1974) cite more than 100 references on both human and animal experiments for seven pollutants, including formaldehyde and benzo-pyrene, in the context of identifying threshold levels for health effects. Source descriptions of the older literature may be found in the NATO reports (1971, 1972, 1973), which detail both toxicological and epidemiological effects grouped by specific pollutants. Waddell (1974) has reviewed a number of primary source studies in the process of deriving one chapter to economic costs of diseases based on statistics from the U.S. Public Health Service, and various reports and studies. Selected source studies on health effects are summarized below as an indication of the large resource literature that exists.

The effects of sulfur oxides and particulates are often difficult to separate due to collinearity of their concentrations. The basic work on a national scale has been provided by the CHESS program. Recently published results (EPA, May 1974) provide data from five study areas selected across the United States; they were: the Salt Lake Basin, Rocky Mountains, Chicago-Northwest Indiana, New York, and Cincinnati. The basic study concentration was on acute and chronic respiratory disease including asthma aggravation, but some correlations with cardiopulmonary symptoms were found in New York.

The published CHESS studies were carried out between 1967 and 1971. In some cases, data from as early as 1940 on population exposure of pollutant measurement were extrapolated. Current monitoring data were obtained from pollutant-specific air quality sensors placed in each community. Each study involved comparisons of several communities within a geographic area. The major conclusions supported the correlation of suspended sulfate concentrations with both increased incidence of asthma and aggravation of cardiopulmonary disease. However, recent reviews of statistical validity of CHESS experimental data indicate that these results are highly speculative. (House Subcommittee on the Environment and the Atmosphere, 1976)

A recent study by Finklea et al. (1975) has formulated "best judgment" dose-effect functions for suspended sulfates. Damage functions were derived from various studies on mortality, aggravation of heart and lung disease in the elderly, aggravation of asthma, excess acute lower respiratory disease in children, and excess chronic respiratory disease. All except mortality showed positive responses below 15 micrograms per cubic meter (ug/m^3) of sulfate concentration; the threshold for mortality effects determined by the study is approximately 25 ug/m^3. The suspended sulfate concentrations are related to sulfur dioxide concentrations by a linear equation, such that in the case of morbidity, 320 ug/m^3 of sulfur dioxide corresponds to a 25 ug/m^3 sulfate level. Thus, effects are shown to occur here even below the primary 24-hour sulfur dioxide standard of 365 ug/m^3.

Another investigation of air pollution effects in a large number of areas has been performed by Lave and Seskin (1973). The relationship between mortality rates and pollutant concentrations was investigated for 117 standard metropolitan statistical areas. Correlations with various socioeconomic indices were investigated by multivariate regression analysis, and sulfate levels were isolated as having a significant association with mortality rates. It was determined that a 10 percent reduction in the level of suspended particulates and sulfates would reduce the mortality rate by 0.9 percent.

Buechley (1973) has investigated relationships between sulfur dioxide and mortality in the New York-New Jersey Metropolitan area. The study utilizes statistical techniques and regression analysis to investigate residual mortality after elimination of meteorological and other covariates. Records over the period from 1960 to 1964 were correlated with 11 levels of sulfur dioxide concentration, indicating that a change in 24-hour levels between 140 and 500 ug/m^3 corresponds to a change in residual mortality in excess of 3 percent.

Results of a study on outpatient medical costs in the Portland, Oregon, standard metropolitan statistical area (SMSA) have been presented by Jaksch and Stoevener (1974). The study utilized records and surveys developed by the Kaiser-Permanente Medical Care Program to investigate the impact of suspended particulate concentration from 60 to 80 ug/m^3 would result in only a 3.5 cent increase in expense per medical visit for respiratory diseases. Recommendations for future study include the determination of impact of pollutants on the number of medical contacts.

The National Academy of Sciences report summarizes investigations of acute and chronic respiratory illness in high oxidant atmospheres, mostly in California, or in laboratory experiments. The report lists aggravation of asthma, decreased cardiopulmonary reserve, increased susceptibility to acute respiratory disease, decrease in pulmonary function, as well as changes in cell physiology, as being prime documented effects of oxidants. Toxicological studies with rabbits (Gardner, 1972) have shown that the stability of cells that prevent lung infection (alveolar macrophages) is reduced at concentrations of 196 ug/m³ (0.10 parts per million-ppm) for 2.5 hours. Experiments with hamsters (Zelac et al., 1971) have shown mutagenic changes (chromosome breaks in white blood cells) when exposed to 392 ug/m³ (0.20 ppm) for 5 hours. Studies with humans (Bates et al. 1973, Hazucha et al. 1973) have shown significant changes in pulmonary function upon exposure to 1,470 ug/m³ (0.75 ppm) and 725 ug/m³ (0.37 ppm) for 2 hours. Asthma attack rate in asthmatics has been found to increase significantly at daily peak oxidant concentrations of 490 ug/m³ (0.25 ppm) (Shoettlin and Landau 1961). These studies and others are listed as being on indicative, but incomplete, data base for photochemical oxidant effects on health. The need for further investigation in both the formulation of dose-response relationships and the validity of the present standards in the light of new evidence was strongly recommended by the panel.

Current studies in health damages are being pursued under the auspices of EPA's Office of Research and Development to estimate the health costs associated with air pollution. One of these studies recently completed by the California Air Resources Board (1975) has estimated "rough order" dose-effect functions compiled by an expert panel using a Delphi approach. The panel generally agreed that patients suffering from viral or bacterial illness would have enhanced susceptibility to oxidant-induced abnormalities. It was deduced that 90 percent of the infected individuals would experience increased dyspnea at 1,560 ug/m³ (0.80 ppm) and increased cough at 1,176 ug/m³ (0.60 ppm). Ten percent of this population would be incapacitated by superimposed bacterial pneumonia (influenza) or acute respiratory failure (viral bronchitis) following exposure to 1,176 ug/m³ (0.60 ppm) of oxidant.

Carbon monoxide is the principal pollutant reviewed in the National Academy of Sciences (NAS) report. Effects on symptoms of cardiovascular disease, behavioral vigilance effects, and effects during pregnancy are presented as the major categories. In an experiment in the Los Angeles area (Aronow and Isbell 1973), a reduction in the time before onset of pain from patients with angina pectoris was observed after breathing carbon monoxide at 56 ug/m³ (50 ppm) for 2 hours. In psychological experiments testing response to environmental stimuli, some indications show that reduction in vigilance and response can occur after exposures of 56 ug/m³ (50 ppm) for 1.5 hours (Beard and Wertheim 1967). The investigations into effects of carbon monoxide exposure on the developing fetus in women during pregnancy have been primarily carried out on animals, and the results are not clearly extrapolatable to humans.

Hexter and Goldsmith (1971) have carried out a regression analysis of daily mortality data in Los Angeles County for the period 1962-65; they considered temperature variations and other cyclic factors as covariates to carbon monoxide concentration. The study indicates a significant correlation of carbon monoxide with mortality, and concludes that the estimated contribution of carbon monoxide between concentrations of 23 ug/m³ (20.2 ppm) and 8 ug/m³ (7.3 ppm) is 11 deaths per day, other factors being equal.

Nitrogen dioxide has been primarily associated with chronic and acute respiratory disease. The NAS study cites the work of Shy et al. (1970) in Chattanooga which tied acute bronchitis rates in infants with differential nitrogen dioxide exposure. Relative incidence of bronchitis was observed to vary as much as 58 percent between low and high exposures. Questions about the validity of nitrogen dioxide measurement methods and the presence of an influenza epidemic have thrown some doubt on the validity of the conclusions; the NAS panel recommends further investigations in this area.

AESTHETIC DAMAGES

Nature and Effects of Air Pollution Damage to Aesthetics

Air pollution reduces the pleasantness of peoples' daily experiences and it can also cause unpleasant experiences that lead to psychic damages. Opinion surveys have shown that the most noted aesthetic effects of air pollution are material soiling and deterioration, irritation of eyes, nose, and throat, malodors, and reduced visibility. These effects are primarily related to the aesthetic aspects of experience rather than to direct physical, health, or economic damages. There is an area of overlap, however, between aesthetic damages and materials damages because of the aesthetic losses from soiling and deterioration.

The primary pollutant responsible for soiling is particulates. Irritation of eyes, nose, and throat is caused primarily by photochemical oxidants. Hydrogen sulfide, produced by anaerobic decomposition of wastes, is a frequent cause of malodor. Reduced visibility is caused primarily by particulates and nitrogen dioxide.

Survey of Source Studies

A summary of the property value studies of primary interest in developing national estimates of the aesthetic benefits of air pollution control is shown in Table 2. These studies employed multiple regression techniques using a variety of pollution level measures, other variables influencing property values, and property values. All study results confirmed the hypothesis that pollution and property values are inversely related, and they found statistically significant coefficients expressing the relationships.

Table 2.
Summary of Property Value Studies

Investigator	Date	Location	Pollution Measure
Ridker-Henning	1967	St. Louis	Sulfation[1]
Zerbe	1969	Toronto	Sulfation
		Hamilton	Sulfation
Anderson-Crocker	1970	St. Louis	Sulfation and suspended particulate
		Kansas City	Sulfation and suspended particulate
		Washington, D.C.	Sulfation and suspended particulate
Crocker	1971	Chicago	Sulfur dioxide and suspended particulate
Peckham	1970	Philadelphia	Sulfation and suspended particulate
Spore	1972	Pittsburgh	Sulfation and dustfall
NAS and NAE	1974	Boston and Los Angeles	Nitrogen oxides and particulates
Nelson	1975	Washington, D.C.	Oxidants

[1] A measure of SO_3 deposition, probably also indicative of particulate levels.

The study of air quality and automobile emission control by the National Academies of Sciences and Engineering provides a more recent estimate of the air pollution damages related to automobiles. This study employed a general equilibrium model of the property market for business, residential, and agricultural land use. Using data on Los Angeles and Boston, the study estimated the national damages from automobile emissions to be in the range of $1.5 to $5 billion, annually.

The bidding game study of pollution control benefits at the Four Corners power plant added a new dimension to the estimation of aesthetic benefits. A questionnaire was administered to local residents and tourists after showing them three sets of photographs, each set showing the aesthetic aspects of different levels of pollution. Bidding games, using realistic payment mechanisms, were designed to determine the maximum amounts that households would be willing to pay for improvements shown in the photographs. The payment mechanisms included sales taxes, electricity bills, monthly payments, user fees, and compensation for environmental damages (Randall 1974).

VEGETATION DAMAGES

The Nature and Effects of Air Pollution Damage to Vegetation

Until recently, studies of the effects of air pollution on vegetation were limited primarily to leaf damage caused by acute exposures in areas adjoining urban centers. However, recent work has begun to change this picture, indicating that vegetation damage is likely to be far more extensive than had been expected.

Measurements of air pollution in rural areas in many states have shown the presence of hazardous concentrations of oxidants over large areas; this condition appears to be the result of the processes of transport and chemical reaction within plumes carried from urban areas. Fluorides, nitrogen dioxide, and sulfur dioxide, with its resultant acid rain, have also been found to have impacts on rural vegetation.

In addition, a number of experimental techniques have been developed to determine the impact of specific pollutants on plant growth. Studies using these techniques have shown that chronic exposure to ozone affects the yield of many crops to a far greater extend than that indicated by leaf damage from acute exposures. Experimental work still in the exploratory stage suggests that oxidants, such as ozone, may destroy chlorophyll and cause reductions in plant growth, which are not manifested by visible injury. Conversely, it appears that acute exposure can cause leaf damage without having a substantial effect on long-term plant growth.

A series of Swedish studies have indicated that the potential effects of sulfur dioxide on vegetation extend far beyond the emission sources and the affected vegetation in the immediate area that is exposed to contact with sulfur dioxide laden air. It appears that sulfur dioxide that is not washed out of the air by rainfall can be transported for distances up to 600 miles and it is exposed to chemical reactions that produce sulfuric acid mist or acid rain. Although acid rain is known to affect vegetation directly, greater damage results in areas where the soils lack sufficient alkalinity to provide a buffer against the acid. The leaching of nutrients by such acids reduces plant growth.

Survey of Source Studies

Damage studies have been performed on a wide variety of agronomic crops, citrus trees, lumber trees, and ornamentals. The largest segment of these studies relates to damage from oxidants and sulfur dioxide, although nitrogen oxides and fluorides have also been implicated; the more important studies are listed in Table 3.

Table 3.
Summary of Vegetation Damage Studies

Study	Date	Location	Pollutants Measured	Effects
Benedict et al.	1973			
Heck et al.	1966	Laboratory	Ozone	Increased damage index
Heck and Brandt	1974	Laboratory	Ozone	5% injury and threshold levels
Botkin et al.	1971	Laboratory	Ozone	Reduction of photosynthesis
Costonis and Sinclair	1969	New York	Ozone	Induced needle blight
Miller	1973	California	Ozone	
Thompson et al.	1972	Riverside	Ozone	Yield reduction in citrus
Davis	1972	Herford, Arizona	Sulfur dioxide	Yield reduction in soybeans
Hill et al.	1974	Utah and New Mexico	Sulfur dioxide and nitrogen dioxide	Foliar injury
Temple	1972	Laboratory	Sulfur dioxide	Foliar injury
McCune	1969	Various studies	Fluorides	Foliar injury and yield reduction in various species

Quantitative relationships between air pollution and vegetation damage have been developed in only a few studies. The NATO criteria documents (November 1971, February 1973, and 1974) for these pollutants contain overall reviews of the literature, as does the chapter by Heck and Brandt (1974) in Stern's air pollution volumes. Jacobson and Hill (1974) contains several hundred primary source references, although damage functions are not specifically addressed. The National Academy of Sciences (1974) publication is the most complete source on fluorides. A recent study for the Environmental Protection Agency (Benedict 1973) has attempted to circumvent physical damage functions by relating source emissions directly to economic losses; this method is suspect, especially for oxidants, as indicated by the recently discovered, high rural oxidant levels shown in the 1973 EPA Trends Report.

Heck and co-workers (1966) have provided a number of studies quantifying ozone damages to various species. In an investigation of damages to one variety each of tobacco and pinto beans, dose-effect functions of a sigmoidal nature were derived. For pinto beans, the injury index for 1 hour of exposure to ozone rose from zero to 90 percent at 0.60 ppm concentration. Chronic effects of ozone are also documented by the data as changing by approximately 15 percent between exposure times of 1 hour and 4 hours. This percentage held true at both high ozone levels and levels near the primary standard of 0.08 ppm. The chronic effects on tobacco showed more than a 20 percent variation in injury between 1 hour and 4 hours of exposure. Heck developed a number of useful visual display techniques for damage functions, illustrating both synergistic effects of pollutants and acute versus chronic effects. He used three-dimensional graphs to simultaneously demonstrate variations in pollutant concentration, exposure time, and resulting damage.

Heck and Brandt (NATO 1974) have shown oxidant damage at the 5 percent level for over 100 plant species on a scatter diagram. Damage envelopes are drawn at the 5 percent and threshold levels for concentrations ranging from 0-2,160 ug/m^3 (0-1.1 ppm) and with time exposures from zero to 8 hours. This effort is useful in providing ranges of damages for a large number of unrelated higher plant species.

A number of studies are available on damages to species of pine trees. Botkin, et al. (1971), Costonis and Sinclair, (1969), and Miller (1973) have investigated pine tree damages. The study by Miller is perhaps the most impressive due to the high damage and death rates found for Ponderosa Pine over a 2-year study period. All of the trees were found to be injured to some degree, and 8.1 percent died during the study. Ambient oxidant readings in the area exceeded 196 ug/m³ (0.10 ppm) for more than an average of 8 hours per day.

Thompson and co-workers (1972) have performed several studies of oxidant effects on citrus tree yields; both ozone and peroxyacyl nitrates have been investigated. Thompson _et al._ (1972) quantified differences in leaf drop, fruit set and drops, and fruit weight per tree on navel oranges. Variance analysis was then performed on the data, and confidence levels given for each value. Addition of ambient ozone to carbon-filtered air was observed to reduce fruit yield by 35 percent.

Sulfur dioxide effects on soybeans have been investigated by Davis (1972). A three-year study was conducted on 485 soybean plots. Sulfur dioxide fumigations were carried out at two growth stages the first two years and at seven stages during the last year. Good correlations were found between leaf area destroyed and reduction of yield. While sulfur oxide exposure is not directly related to yield loss, the study is important in indicating a possible general link between leaf loss and yield loss resulting from sulfur oxide exposures.

Hill _et al._ (1974) have carried out one of the most massive studies based on the number of species involved. About 80 native desert species in Utah and New Mexico were examined for sulfur and nitrogen dioxide effects under field conditions. Fumigation levels ranged from 1,430 ug/m³ (0.5ppm) to 25,600 ug/m³ (10 ppm) sulfur dioxide concentration; most species for which data was complete showed a marked injury increase at either 6 or 10 ppm concentration. While these are much higher than normal ambient levels, the study was intended to simulate effects in a power plant plume.

Four ornamental species, Chinese elm, Norway maple, ginkgo, and pin oak, were fumigated with sulfur dioxide in controlled environmental chambers by Temple (1972). Three dimensional dose-response curves similar to those of Heck were constructed for each species. Damages to foliage of up to 95 percent were found at concentrations of 11 ug/m³ (4 ppm) after 6 hours of exposure. This study fails to provide data near ambient urban levels of 365 ug/m³ (0.14 ppm) or less, but a small amount of damage was observed at 715 ug/m³ (0.25 ppm) over time periods of 30 days.

The effects of other pollutants are not well documented. McCune (1969) has done research on fluorides, but this pollutant is not widespread in ambient air. Particulates have been found to show slight effects due to limitation of photosynthesis. Nitrogen oxides and carbon monoxide have shown no appreciable effects in the few studies that have been performed.

MATERIALS DAMAGES

The Nature and Effects of Air Pollution Damage to Materials

A wide variety of air pollutants cause damages to materials. Sulfur dioxide corrodes metals, particulary galvanized steel; it also attacks cotton textiles, finishes and coatings, paints, building stone, electrical and electronic equipment, paper, and leather. Ozone has been shown to shorten the life of rubber products, dyes, and paints. Nitrogen oxides also cause fading of dyes and paints. Particulates cause deterioration and soiling of stone, clay, and glass structures and products. These damaging effects are experienced by society in a number of ways. In many cases, avoidance costs are additional because research and development has been needed to develop new materials more resistant to attack by air pollution. These new materials are sometimes more expensive than those more susceptible to damage. Society also bears the costs of cleaning and repairs, including the replacement of failed or deteriorated components and structures. In some cases, the failure of a material can cause damages.

Survey of Source Studies

Best documentation for damage to materials covers the effects of sulfur dioxide, ozone, and nitrogen dioxide. Particulates have been shown to have effects on soiling of paints and building materials. Surveys of physical damage functions may be found in Yocom and McCaldin (1968) and the NATO criteria documents for particulates (1971), sulfur dioxide (1971), and photochemical oxidants (1974). Much of the recent work in both ambient air and controlled chamber studies has been pursued at EPAs National Environmental Research Center in Triangle Park, N.C. Economic estimates based on physical damage studies have been made by Salmon (1970), Gillette (1974), Haynie (1974), and Waddell (1974). The major damage studies are summarized in Table 4.

Table 4.
Summary of Materials Damage Studies

Study	Date	Pollutants Measured	Effects
Upham	1965	Sulfur dioxide	Metal corrosion
Haynie and Upham	1970	Sulfur dioxide	Zinc corrosion due to sulfur dioxide and humidity
Beloin and Haynie	1973	Particulates	Soiling
Booz Allen and Hamilton	1970	Particulates	Soiling
Michelson and Tourin	1967	Particulates	Paint Soiling
Upham *et al.*	1974	Nitrogen dioxide	Textile dye fading

The most comprehensive survey of economic losses incurred from air pollution damage to materials is the work of Salmon (1970). Thirty-two categories of materials were the basis for calculating a total economic loss of $3.8 billion due to air pollution. The pollutants, in decreasing order of economic importance, were found to be sulfur oxides, ozone, nitrogen oxides, carbon dioxide and particulates. Waddell has used parts of this study, combined with in-depth studies on specific categories, to arrive at an estimate for the cost of materials losses in 1970.

Haynie (1974) has assessed economic damages to metals, paints, elastomers, electrical contacts and electronic components at $2.7 billion per year. The percentages of total economic loss and available reference material are given for metals, paints, textiles, elastomers, and plastics. Each area is also rated as to whether there is strong or weak evidence of damage or only a suspected relationship. This approach clearly defines areas requiring further investigation.

Economic damage due to sulfur dioxide has been estimated by Gillette (1974), both on a national and regional basis; the estimate shows significant reductions in sulfur dioxide levels nationwide between 1968 and 1972. These calculations were carried out for various SMSAs using the air quality at the center of the city as representative of the entire SMSA. Reductions of damages due to sulfur dioxide were calculated to decrease from $900 million to $75 million over the 5-year period. This loss was determined to occur mostly from corrosion of painted or unpainted surfaces.

Physical damage studies pertaining to materials are not available on a comprehensive basis, but studies that have been done on specific materials are usually better quantified than studies on health or vegetation damage due to the lack of biological complications. The studies presented below are representative of the backup data which support the economic damage functions.

Metal corrosion is the most economically significant category. A number of studies have been completed on metal corrosion caused by sulfur dioxide. One of the most illustrative for widespread geographic interpretation was a study by Upham (1965) on metal corrosion in eight major cities. Values of corrosional weight loss between levels of 0.02 and 0.14 ppm annual sulfur dioxide concentration vary from 4 to 12 grams, respectively. Except for one city, the data very nearly fits a straight line dose-response function. Corrosion of zinc has been investigated by Haynie and Upham (1970); sulfur dioxide and relative humidity were determined to act synergistically in the corrosion process. Significant reductions in useful lifespan were predicted even at sulfur dioxide concentrations as low as 130 ug/m^3.

Good correlation of soiling of painted and unpainted surfaces with particulate concentration has been found by Beloin and Haynie (1973) for a variety of substances. Dose-effect functions were developed by regression analysis and particulates were found to account for up to 92 percent of the variability of reflectance for certain substances. Whether or not this physical change can be linked to changes in maintenance frequency is not yet clear. Studies by Booz Allen and Hamilton (1970) in the Philadelphia area demonstrated no correlation with particulate concentration between 50 and 150 ug/m^3, while a study by Michelson and Tourin (1967) showed more than four times as much repainting was done in areas with 250 ug/m^3 concentration than in areas with 50 ug/m^3 concentration. However, the transgeographic nature of the study leaves these results open to question.

Nitrogen dioxide has been only tentatively linked to significant materials damage. A recent study by Upham *et al.* (for EPA) has indicated that certain cellulosic fibers may be affected by nitrogen dioxide. Controlled test chambers were employed to investigate both nitrogen dioxide and relative humidity effects. Correlation of nitrogen dioxide concentration with dye fading was found, as well as evidence of a synergism with relative humidity. This correlation is supported somewhat by the cost study of Salvin, which linked sulfur and nitrogen oxides and acids to changes in textile fibers and dyes.

MORE ELUSIVE DAMAGES

As pointed out on repeated occasions, the current state-of-the-art in benefit assessment does not permit full estimation of all the damages associated with air pollution. For example, in assessing the damages to human health, the costs of lost leisure time and psychic costs are not adequately reflected in estimates of the economic cost of illness. In other cases, the effects themselves have not yet been adequately defined, as in the case with the risk of large-scale ecological disruptions. With some types of damage, both the effects and the damage values elude adequate definition. Additional damage categories that have been excluded from the discussion presented above include:

- Unquantified health effects
- Animal health
- Natural environment.

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Chapter 3
The Costs of Controlling Air Pollution

1. INTRODUCTION

This 1975 estimation of the total incremental costs that will be required to meet the provisions set forth by the Clean Air Act is significantly different from the estimates presented in the 1974 Cost of Clean Air Report for the following reasons:

1. Costs for more industries have been included, providing a broader base than previous reports.

2. Compliance dates for some standards are different.

3. More detailed analysis has been performed on the Transportation Control Plans costs.

All major industrial pollutant sources which were included in the 1974 report are reevaluated in this report. In addition, costs have been estimated for the following industrial sources which have been added to make this report more comprehensive:

1. Clay construction products
2. Coal gasification plants
3. Paint manufacturers
4. Printing establishments
5. Surface coatings facilities
6. Petrochemical industry
7. Nonfertilizer phosphate reduction products
8. Building and industrial incinerators.

This report assumes that the compliance date for some scrubber installations in the electric utility plants will be extended to as late as July 1, 1980. This assumption will postpone some of the investment cost for as much as five years, and it will also reduce the annual cost of operating pollution control equipment and the cash requirements of the electric utilities sector to some extent during the period 1975-80.

Air pollution control costs passed on to the purchasers of light-duty motor vehicles have been calculated based upon statutory emission control requirements and related regulations. The reduction in new car sales during the 1975 model year, and future estimates of reduced car sales resulted in lower control costs than were previously estimated because control costs are calculated on the basis of new car sales.

Estimates of the costs associated with State Transportation Control Plans were made on a more detailed basis in this report and exceed the $2 billion estimate reported in the 1974 cost report.

2. GOVERNMENT EXPENDITURES FOR AIR POLLUTION CONTROL

The Clean Air Amendments of 1970 (P.L. 91-604) impose somewhat different requirements on governmental agencies than on others affected by the legislation. Although there will be some expenditures for abatement of pollution from government owned facilities, the principal purposes of expenditures in the government sector are for research, monitoring, administration, and enforcement. Research is mainly supported by Federal funds, while state and local funds, supplemented by Federal grants, are used primarily to implement, operate, and maintain monitoring and enforcement programs.

Detailed analyses are not presented here, since the main purpose of this effort is to determine the magnitude of this category of expenditures relative to other expenditures estimated in the report. The discussion concentrates on two basic categories: program costs and costs for controlling pollution at Federal facilities.

Program Costs

Table 2-1 shows projected governmental expenditures broken down by EPA and subfederal categories. A stable rate of expenditure after FY 1978 is anticipated due to governmental revenue constraints and competing social needs.

Table 2-1
Projected Local, State and Federal Air Quality Program Costs

(By Fiscal Years in Millions of Dollars)

	1976	Transition[2]	1977	1978	1979	1980	1981	1982	1983	1984	1985	Total
EPA[1]	78	19	90	94	94	94	94	94	94	94	94	939
State & Local	156	39	193	210	210	210	210	210	210	210	210	2068
Total	224	58	283	304	304	304	304	304	304	304	304	3007

[1] Excluding grants to state, interstate, and local governments which are included in that category.
[2] July 1, 1976 through September 30, 1976 for converting Federal fiscal year to October 1-September 30.

Federal Program Costs

The Clean Air Act authorizes a national program of air pollution research, regulation, and enforcement activities. Under the Act, primary responsibility for the prevention and control of air pollution rests with State and local governments, with the program directed at the Federal level by EPA. EPA's role is to conduct research and development programs, set national environmental goals, ensure that adequate standards and regulations are established to meet these goals, provide assistance to the States, and ensure that the standards and regulations are effectively enforced.

The environmental standards are the National Ambient Air Quality Standards (NAAQS). These standards set forth the allowable concentration in air of pollutants which affect human health and public welfare. The health and other effects of pollutants are delineated in criteria documents which are the basis for the standards. National Ambient Air Quality Standards have been set for total suspended particulates, sulfur dioxide, nitrogen dioxide, carbon monoxide, photochemical oxidants, and hydrocarbons. Two types of standards are set: primary standards to protect human health and secondary standards to protect the public welfare (prevention of damage to property, animals, vegetation, crops, visibility, etc.). Controlling emissions to meet standards is handled through two major types of activities: (1) States carry out State implementation plans (SIPs) which control pollution primarily by preceiving specific emission limitations or control actions for types of polluters and (2) EPA controls emissions from new motor vehicles and selected stationary sources.

Program emphasis will continue to be on the attainment and maintenance of the National Ambient Air Quality Standards. Because the implementation of control actions is basically the responsibility of the State and local governments, it will be required that they take on increased responsibilities for air pollution control if the standards are to be attained, particularly if automotive-related pollutants are to be controlled. The State control plans incorporate controls for automotive related pollutants since reductions achieved as a result of the Federal motor vehicle control program are not sufficient to attain the standards for such pollutants in many areas. The Federal program places primary emphasis on increasing State and local control agencies' ability to control air pollution.

In order to attain the standards, efforts are to concentrate on the implementation of State implementation plans, their reassessment, and revision if indicated. For maintenance of the standards, many SIPs will have to be revised to include the controls required to assure that the ambient air quality standards are not violated in the future. The governors of 45 States have been formally notified by EPA Regional Administrators that the SIPs for their states must be revised in order to attain and maintain the NAAQS. Plan revisions are necessary in 31 States for particulate matter; 12 States for sulfur dioxide; 22 States for carbon monoxide; 29 States for photochemical oxidants; and 3 States for nitrogen dioxide.

The nature and magnitude of the problems associated with attainment and maintenance of the NAAQS varies with the specific pollutant involved. Federal programs will be aimed at the formulation of methodologies for developing control strategies and the development of control systems as well as to the support of State and local programs. Maintenance of the standards in the long term will also be facilitated by Federal programs that lead to the minimization of emissions from new sources (i.e., new motor vehicle emission standards and standards of performance for new stationary sources) and the assurance of continued low emissions performance for these sources during their useful lives.

Program expenditures by the Agency are expected to remain level for the next several years, with the states gradually assuming greater responsibility for implementation of the various provisions of the Act. Table 2-2 shows projections for the three major appropriations categories.

Table 2-2.
Projection of Federal Program Expenditures by Category

(By Fiscal Years in Millions of Dollars)

	1976	Transition[2]	1977	1978	1979	1980	1981	1982	1983	1984	1985	Total
Abatement and Control[1]	63	16	89	94	94	94	94	94	94	94	94	920
Enforcement	13	3	14	18	18	18	18	18	18	18	18	174
Research and Development	36	9	44	40	40	40	40	40	40	40	40	409
Total	112	28	147	152	152	152	152	152	152	152	152	1,503

[1] Includes grants to state, interstate, and local government.
[2] July 1, 1976 through September 30, 1976, for converting Federal fiscal year to October 1, through September 30.

Expenditures by Other Federal Agencies

The following information is excerpted and adapted from: Office of Management and Budget, "Special Analyses: Budget of the United States Government", USGPO 1976.

Although covering a wide range of activities, Federal environmental programs are classified in three broad categories: pollution control and abatement; understanding, describing and predicting the environment, and environmental protection and enhancement activities. It is difficult to attribute non-EPA Federal expenditures to specific pollution control legislation in many cases, but an approximation of P.L. 91-604 related expenditures is given by the air quality expenditures in the Pollution Control and Abatement category. Principal activities in this category include actions necessary to reduce pollution from Federal facilities; the establishment and enforcement of standards; research and development; and the identification of pollutants, their sources, and their impact on health. Non-EPA air quality expenditures by the Federal government in FY1976, the transition quarter and FY1977 are 186, 46 and 209 million dollars, respectively.

Since Federal spending is strongly influenced by policy and competing social needs, forecasting is always problematical. The best estimate currently is that such expenditures will remain stable over the next several years, with only minor growth or decline. If non-EPA Federal outlays in this category were to be held constant at the FY1977 level, total decade expenditures would be about 2.1 billion dollars. While this is a large amount on an absolute basis, it is relatively small compared to total expenses in the nation for P.L. 91-604.

3. CONTROL OF EMISSIONS FROM STATIONARY SOURCES

For the purposes of this report, stationary sources are considered to include industrial sources, utilities, and industrial/commercial heating and incineration which are treated as industries. Dry cleaning establishments, paint shops, and other small scale activities are also considered as industries.

Service stations are considered under the Mobile Source section because they are controlled for vapor emissions under Transportation Control Plans.

Classification of Industrial Sources

In order to calculate air pollution control costs, industries are represented by "segments" and "model plants".

A "segment" is all or a portion of an industry that has: (1) the same production process, (2) the same air pollution control technology, and (3) the same pollution control standard. For example, the Kraft Paper Industry is dealt with for purposes of air pollution control costs in terms of 10 different segments. These segments are defined in Table 3-1.

Table 3-1.
Kraft Paper Industry Segment Definitions

Process		Control Technology	Pollution Standard
1.	Power Boiler	Electrostatic Precipitators	Federal Particulates
2.	Boiler	Double Alkali Scrubber	Federal Sulfur Dioxide
3.	Recovery Furnace	Electrostatic Precipitators	Washington/ Oregon Particulates
4.	Recovery Furnace	Venturi Scrubber	Washington/ Oregon Particulates
5.	Recovery Furnace	Recovery Furnace Replacement	Washington/ Oregon Total Reduced Sulfur
6.	Recovery Furnace	BLO	Washington/ Oregon Total Reduced Sulfur
7.	Smelting Tank	Orifice Scrubber	Washington/ Oregon Particulates
8.	Lime Kiln	Venturi Scrubber	Washington/ Oregon Particulates
9.	Stock Washer	Incinerate in Recovery Furnace	Washington/ Oregon Total Reduced Sulfur
10.	Evaporator	Incinerate in Lime Kiln	Washington/ Oregon Total Reduced Sulfur

"Model plants" are the building blocks of a segment; that is, a segment capacity for production is comprised of a number of model plants that are classified as either "existing" or "new" (new facilities are those constructed after the date when the New Source Performance Standards are in effect for that industry). For example, Segment 7 for Kraft Paper (Smelting Tanks) has three model plant sizes (454, 907, and 1,361 units of production per day). There are existing facilities in all three sizes, but during the 1975-85 period, new facilities are expected to be built in only the middle size class. Table 3-2 lists the industries for which air costs are calculated, the number of segments for those industries, and the Standard Industrial Classification (SIC) industry code as defined by the Office of Management and Budget (OMB).

Table 3-2.
Segments for Industrial Cost Analysis

Name	Existing Segments	SIC (1972 Definition)
Steelmaking	22	331 (pt)
Steel Foundries	1	3324.5
Ferroalloy	5	3313
Steel-Coke	3	331 (pt)
Steel-Scintering	7	331 (pt)
Solid Waste Disposal	6	4953
Sludge Incineration	1	4953
NSSC Paper	2	2611272
Primary Zinc	1	33331
Primary Lead	1	33321
Secondary Zinc	1	33414
Secondary Aluminum	1	33417.8
Industrial Heating	1	N/A
Commercial Heating	1	N/A
Crude Oil Storage	1	291X
Gasoline Storage	1	291X
Jet Fuel Storage	1	291X
Refining	1	291X
Petroleum Cost Cracking	2	291X
Primary Aluminum	3	33347
Natural Gas	2	1321
Coal Cleaning	1	1211 (pt), 12136
Iron Foundries	5	3321.2
Dry Cleaning	3	7215.6
Grain Handling	1	5153
Feed Mills	1	2047.8
Asphalt	2	29510
Cement	4	3241
Sulfuric Acid	2	28193
Nitric Acid	1	2873
Phosphate Fertilizer	4	2874
Kraft Paper	10	2611231.35.39.43
Lime	3	3274
Primary Copper	3	33311
Secondary Lead	1	33412
Secondary Brass	2	3362
Asbestos	6	3292
Clay Construction Products	3	1452.3.4.5.6.7.8.9; 3295
Coal Gasification	2	N/A
Petrochemicals	7	2869

Table 3.2. (Continued)
Segments for Industrial Cost Analysis

Name	Existing Segments	SIC (1972 Definition)
Nonfertilizer Phosphate	3	2819
Mercury Cell Chlor Alkali	2	2812
Commercial and Industrial Building Incineration	2	N/A
Surface Coatings	4	3711.12.13.14.15; 3631.32.33.34;3479; 7531.35
Paint Manufacture	2	2851
Painting	1	2751.52.53.54; 2711.21.31

The cost of controlling air pollution from industrial sources is estimated for model plants. All existing and new capacity is expressed in terms of the model plants. For example, the smallest model plant in Segment 7 for Kraft Paper has to spend $54,000 for capital equipment to control particulates. In summary, this model plant is defined by:

- Industry - Kraft
- Production process - Smelt Tank
- Control technology - Orifice Scrubber
- Pollution standard - Washington-Oregon Particulates
- Model plant capacity - 454 Units
- Type of facility - Existing.

Costs Related to Required Reduction in Air Emissions

The control costs that industries incur are directly, but usually not linearly, related to the amount of reduction in the emissions required. Since the purpose of this section is to estimate the control costs resulting from provisions of the Clean Air Act, it is necessary to factor out the levels of control that existed in industries prior to the Clean Air Act. Controls could have existed prior to 1971 because it was economically worthwhile to recover byproducts or because there were prior emission regulations (either self-imposed or government-generated).

REDUCTIONS IN EMISSIONS PRIOR TO THE CLEAN AIR ACT

Byproduct Recovery. In some industries, it is common to control particulate or sulfur oxides emissions in order to recover materials in these gases that have economic value. Where this was common practice prior to 1971, the associated control costs are not calculated in this report. Some byproduct recovery values are, however, calculated in this report. Such values are calculated when the controls were prompted by State Implementation Plans (SIP) that responded to requirements of the Clean Air Act. For example, petroleum storage tanks are controlled by SIP's to reduce the hydrocarbon emissions. In most cases, the value of the fuel recovered by the control devices placed on these storage tanks is greater than the cost of the control devices. Thus, the control saves industry money rather than causing a net cost to the industry.

Average Industrial Controls Prior to the Clean Air Act. An attempt has been made to estimate the average level of control in each industry prior to the date that each industry was impacted by the provisions of the Clean Air Act. For new facilities in a specific industry built during the late 1970's and early 1980's, it is assumed that they will have installed pollution equipment equal to the average practice that existed prior to the Clean Air Act. Therefore, costs are estimated for the incremental amount of pollution equipment needed to meet the current emission standards.

REDUCTIONS IN AIR EMISSIONS REQUIRED BY THE CLEAN AIR ACT

The Clean Air Act affects pollution control through: (1) ambient standards for six pollutants [particulates, sulfur oxides (SO_x), nitrogen oxides (NO_x), hydrocarbons (HC), oxidants, and carbon monoxide (CO)], (2) New Source Performance Standards (NSPS) which are emission standards, (3) emission standards for three hazardous pollutants (mercury, asbestos, and beryllium), (4) control of fuel additives (e.g., lead), (5) control of non-criteria, non-hazardous pollutants, (6) aircraft standards, and (7) "no significant deterioration" requirements.

Federal Ambient Standards and State Implementation Plans. In order to meet the ambient standards set by EPA, states must devise plans that take into account the unique characteristics of metropolitan and other local areas with regard to the size and mix of pollutant sources, meteorology, terrain, etc. State Implementation Plans control pollution from industrial sources based upon local conditions. For example, Oregon and Washington place stringent controls on existing Kraft pulp mills, whereas many states have no existing Kraft pulp mills, and therefore no present controls. For some industries, such as Steelmaking, some states have more stringent emission controls than others. In fact, in this report, steel mills are classified into four categories based upon the stringency of various state air emission controls.

Effectively, the SIP's translate the Federal ambient air standards into sets of emission standards for particulates, sulfur oxide, nitrogen oxide, hydrocarbon, and carbon monoxide.

Some of these types of state differences in controlling existing facilities are taken into account in this report. With regard to new plants, there is much less state differentiation because there is a set of Federal controls for new facilities called New Source Performance Standards (NSPS).

New Source Performance Standards. New Source Performance Standards have been promulgated for only a portion of the industries that will eventually be covered; Table 3-3 shows the industries that are presently covered under NSPS and the associated emission factors. The sources for the data in this table are references 1 through 7 which are contained in the listing at the end of Table 3-3. Industries for which NSPS are not yet promulgated are assumed to have the same cost functions as these subject to SIP regulations.

Table 3-3.
New Source Performance Standards Regulations

Source	Pollutant	Emission Standard[1]	Suitable Control Technology
1. Steam Electric Generators	Particulates	0.2 lb/10^6 Btu heat input (0.36 g/10^6 cal)	Electrostatic Precipitator
	SO_2 (liquid fossil fuel)	0.8 lb/10^6 Btu heat input (1.4 g/10^6 cal)	Scrubber (lime slurry) or low-sulfur fuel switch
	SO_2 (solid fossil fuel)	1.2 lb/10^6 Btu heat input (2.1 g/10^6 cal)	Scrubber (lime slurry) or low-sulfur fuel switch
	NO_x (gaseous fuel)	0.2 lb/10^6 Btu heat input (0.36 g/10^6 cal)	Combustion Modifications
	NO_x (liquid fuel)	0.3 lb/10^6 Btu heat input (0.54 g/10^6 cal)	Combustion Modifications
	NO_x (solid fuel)	0.7 lb/10^6 Btu heat input (1.26 g/10^6 cal)	Combustion Modifications
2. Municipal Incinerators		0.10 grain/SCF dry flue gas (chngd to 12% CO_2) 1.9 lb/T (0.95 Kg/MT)	Electrostatic Precipitator or Venturi Scrubber
3. Portland Cement Plants	Particulates (kilns)	0.30 lb/T of dry feed (0.15 Kg/MT	Baghouse
	Particulates (clinker coolers)	0.10 lb/T of dry feed (0.05 Kg/MT	Baghouse
4. Nitric Acid Plants	NO_x	3.0 lb/T of acid, avg over 2 hrs. (1.5 Kg/MT)	Catalytic NO_x Decomposition Systems
5. Sulfuric Acid Plants	SO_2	4.0 lb/T of acid (100%) (2 Kg/MT)	Dual Absorption Plant or Sodium Sufite/Bi-sulfite Scrubber
	Acid Mist	0.15 lb/T (0.075 Kg/MT)	
6. Asphalt Concrete Plants	Particulates	70 mg/Nm^3	Fabric Filter or Venturi Scrubber
7. Petroleum Refineries	Particulates	50 mg/Nm^3	Electrostatic Precipitator
(FCC Catalyst Regeneration)	CO	0.050 volume %	Electrostatic Precipitator
(Process Gas Burning)	H_2S	230 mg/Nm^3 of fuel gas	Electrostatic Precipitator

Table 3-3. (Continued)
New Source Performance Standards Regulations

8.	Hydrocarbon Vessels (Storage Tank)	Hydrocarbons	Require Floating Roof Tank	Floating Roof Tank
9.	Secondary Lead (Reverberatory Furnace)	Particulates	50 mg/Nm^3	Fabric Filter or Scrubber
10.	Brass and Bronze Ingot (Furnace)	Particulates	50 mg/Nm^3	Fabric Filter
11.	Iron and Steel (BOF)	Particulates	50 mg/Nm^3	Open-Hood Scrubber or Electrostatic Precipitator or Closed-Hood Scrubber
12.	Sewage Sludge Incineration	Particulates	70 mg/Nm^3	Venturi Scrubber
13.	Ferroalloy (Electric Submerged Arc Furnace)	Particulates	0.99 lb/MW-hr (0.45 kg/MW-hr)[2]	Baghouse
			0.51 lb/MW-hr (0.23 kg/MW-hr)[3]	Electrostatic Precipitators Scrubber
		CO	20% CO by volume	Afterburner
14.	Iron and Steel (Electric Arc Furnace)	Particulates	0.0052 gr/dry scf (12 mg/dry scm) 5% opacity (but there are many exceptions)	Direct shell evacuation (DSE) with either building evacuation or canopy hoods. Or, DSE with canopy hoods and natural ventilation through the open roof.
15.	Primary Primary Potroom	Inorganic Fluorides Visible Emissions (particulates, fluorides)	2 lb/ton (1 kg/MT) of aluminum produced from both Potroom and Bake Plant	Wet gas scrubber in series with an electrostatic precipitator or fabric filters using alumina absorbant

Table 3-3. (Continued)
New Source Performance Standards Regulations

	Anode Bake Plant	Inorganic Fluorides Visible Emissions (particulates, fluorides)		Wet scrubber in conjunction with a wet electrostatic precipitator or clean residual fluoride-bearing cryolite from anode remnants before recycling
16.	Phosphate Fertilizer Plants			
	Wet Process Phosphoric Acid Plants	Inorganic Fluorides	0.020 lb/ton (10 g/MT) of equivalent P_2O_5 feed	Cross-flow spray packed scrubber
	Superphosphoric Acid Plants	Inorganic Fluorides	0.010 lb/ton (5.0 g/MT) of eqvlnt P_2O_5 feed	Cross-flow spray packed scrubber
	Diammonium Phosphate Plants	Inorganic Fluorides	0.060 lb/ton (30 g/MT) of equivalent P_2O_5 feed	Cross-flow spray packed scrubber
		Visible Emissions (particulates, fluorides)	20% opacity	
	Triple Superphosphate	Inorganic Fluorides	0.20 lb/ton (100 g/MT) of eqvlnt P_2O_5 feed	Cross-flow spray packed scrubber
		Visible Emissions	20% opacity	
	Granular Triple Superphosphate Storage	Inorganic Fluorides	5.0×10^{-5} lb/hr/tn (0.25 g/hr/MT) of equivalent P_2O_5	Cross-flow spray packed Scrubber
		Visible Emissions	20% opacity	
17.	Coal Cleaning Facilities			
	Wet Cleaning Systems	Particulates	0.031 grain/dry scf (0.06 mg/dry SCM)	High efficiency, venturi type wet scrubbers
	Dry Cleaning Systems	Particulates	0.018 grain/dry scf (0.029 mg/dry SCM)	Fabric filters

[1] Not to exceed the amount given.

[2] When producing silicon metal, ferrosilicon, calcium silicon, or silico-manganese zirconium.

[3] When producing high carbon ferrochrome, charge chrome, standard ferromanganese, silico manganese, calcium carbide, ferrochrome silicone, ferromanganese silicon, or silvery iron.

References for Table 3-3.

1. Background Information for Proposed New Source Performance Standards: Steam Generators, Incinerators, Portland Cement Plants, Nitric Acid Plants, Sulfuric Acid Plants. U.S. Environmental Protection Agency, Research Triangle Park, North Caroline. APTD-0711. 50 p., August 1971.

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3. Background Information for Standards of Performance: Primary Aluminum Industry Volume 1: Proposed Standards. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 450/2-74-020a. 99 p., October 1974.

4. Background Information for Standards of Performance: Electric Arc Furnaces in the Steel Industry Volume 1: Proposed Standards. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 450/2-74-017a. 155p., October 1974.

5. Background Information for Standards of Performance: Electric Submerged Arc Furnaces for Production of Ferroalloys Volume 1: Proposed Standards. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 450/2-74-018a. 147 p., October 1974.

6. Background Information for Standards of Performance: Phosphate Fertilizer Industry Volume 1: Proposed Standards. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 450/2-74-019a. 119 p., October 1974.

7. Background Information for Standards of Performance: Coal Preparation Plants Volume 1: Proposed Standards. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 450/2-74-021a. 40 p., October 1974.

Hazardous Air Substances. The costs of control (as measured by either the cumulative investment over a ten-year period or the annual costs) are relatively small for those industries controlling hazardous substances in comparison to the control costs for other industries. The industries affected by hazardous substances regulations to date are:

- Chlor-Alkali and Primary Mercury for mercury emissions

- The Asbestos industry and construction and demolition operations for asbestos emissions

- Primary Beryllium for beryllium emissions.

Methods for Controlling Air Emissions from Stationary Sources. The most common pollutants that industrial sources have to control are particulates and sulfur oxides. Of the thirty-nine industries evaluated in this report, twenty-two must control for particulates and nine must control for sulfur oxides.

1. **Particulate Control Devices.** In simplest terms, particulates are controlled by using electrostatic precipitators (ESP), scrubbers, or filters. The scrubbers are usually a wet process that generates a water effluent problem in the water medium. ESP and filters are usually dry processes insofar as the extraction of particulates from the air is concerned, but plants often choose to dispose of the extracted particulates via a water stream. When this is done, a water problem is also created. Several of these intermedia impacts are dealt with in this report.

Plants often put several control devices in series or use various types of control devices within the category of scrubber. For example, a segment of the Primary Aluminum industry employs a primary collector (hoods and ducts), a wet ESP, and spray tower (scrubber) in series. Different segments of the Kraft pulp mill industry employ cyclonic scrubbers, Venturi scrubbers, and orifice scrubbers. The individual industry descriptions will explain the control techniques assumed in each case. These examples are provided here to highlight the intermedia problem and to place the control devices into some common categories that are easy to understand.

Electrostatic precipitators are employed for particulates that can be ionized and separated from a gas stream by electrical means. Scrubbers usually employ water to "wash" particles out of a gas stream. Filters are used to remove particles that can be trapped as the gas stream moves through a fabric media. Filters are gaining in application because the new fiberglass filters can be employed at very high temperatures (up to 550°F).

There are a group of miscellaneous control devices that also can be used for particulate reductions. These include afterburners, hoods, and building evacuation (where the building is sealed tight and workspace emissions are collected at vented locations).

2. **Sulfur Oxide Control Devices.** The most common control devices for sulfur oxides are scrubbers, absorbers, and acid plants. The scrubbers are of the amine, lime, limestone, or lime/limestone type. Often an acid plant (a control technique that recovers sulfuric acid from the sulfur gas) such as a Claus plant is used in conjunction with a scrubber to obtain a valuable byproduct that can be sold. Claus recovery plants must themselves be controlled with a tail-gas treatment facility.

3. **Nitrogen Oxide Control Devices.** The only industry for which nitrogen oxide controls are explicitly considered in this report is the Nitric Acid industry. Nitric acid plants reduce nitrogen oxide emissions by employing catalytic reduction devices. In this method of control, the gas is treated with a catalytic reduction technique that uses natural gas, ammonia, or hydrogen. Use of natural gas dominates because of its lower costs and proven ability. However, the increasing shortages of natural gas could alter its use in the future.

4. **Hydrocarbon Control Devices.** Petroleum, Dry Cleaning, Paint Manufacture, Surface Coatings, and Printing are industries that must control hydrocarbon emissions. Petroleum storage controls tend to be handled by installing floating roofs on the storage tanks; this is almost always a profitable byproduct recovery process. Dry cleaning emissions will be reduced by switching material reports. Printing emissions are reduced by using thermal incinerators.

5. **Carbon Monoxide Control Devices.** Carbon monoxide emission controls are considered only for the Petroleum Industry. Carbon monoxide is burned along with hydrocarbons to form less noxious gases. This burning takes place in waste-heat boilers, and the energy generated in this burning is often used to economic advantage by the industry. In some existing refineries, the additional steam generated by these boilers cannot be used, but new plants can be designed to take advantage of this means of reducing their total energy requirement.

6. Pretreatment Options. Quite often, it is very efficient to reduce the emissions from a plant by changing fuels or making some kind of process change. Two cases where this is often practiced are the Steam Electric Power Plants and Dry Cleaning. As the summaries for these two industries show, assumptions are made about the amount of fuel switching and solvent fluid used, respectively.

Industrial Descriptions and Assumptions. The industry summaries and assumptions are presented in the sequence listed in Table 3-4, and they describe each source in terms of the industry characteristics, emissions, control technology, and costs of control.

Table 3-4.
Industrial Sector Coverage for Air Pollution Control Analysis of Stationary Sources

Sequence	Industry
1	Coal Cleaning
2	Coal Gassification
3	Natural Gas Processing
4	Feed Mills
5	Kraft Pulp Mills
6	NSSC Pulp Mills
7	Printing
8	Mercury Cell Chlor-Alkali
9	Nitric Acid
10	Paint Manufacture
11	Phosphate Fertilizer
12	Nonfertilizer Phosphate
13	Sulfuric Acid
14	Petrochemicals
15	Petroleum
16	Ferroalloy
17	Iron and Steel
18	Iron Foundries
19	Steel Foundries
20	Primary Aluminum
21	Secondary Aluminum
22	Primary Copper
23	Secondary Brass and Bronze
24	Primary Lead
25	Secondary Lead
26	Primary Zinc
27	Secondary Zinc
28	Asbestos
29	Asphalt Concrete
30	Cement
31	Lime Manufacture
32	Clay Construction Products
33	Surface Coatings
34	Steam Electric Power Plants
35	Solid Waste Disposal
36	Sewage Sludge Incineration
37	Grain Milling
38	Dry Cleaning
39	Industrial and Commercial Heating

COAL CLEANING INDUSTRY

Production Characteristics and Capacities. In 1972, which is the last year that Bureau of Mines data was available, the total production of bituminous and lignite coal in the United States was about 540 million metric tons. The annual production rate has gone both up and down in recent years, but the net change from 1968 to 1972 was an increase of about 9 percent. The 1972 production came from 4,879 mines. About 51 percent of the production came from underground mines, 46 percent from strip mines, and 3 percent from auger mines. The trend over recent years has been toward fewer mines and toward a greater dependence on strip mining. The number of underground mines has been decreasing, largely because of the strict regulations of the 1969 Coal Mine Health and Safety Act.

In the mining of coal, various inert materials and other impurities, such as pyritic sulfur, are recovered along with the coal. If these materials are present in sufficient quantity, they must be removed by coal cleaning. This cleaning process increases the heating value of the coal and reduces the amount of pollutants emitted when the coal is burned.

In strip mining where the coal seams are uncovered, the amount of impurities in the coal is relatively low, and only about 32 percent of the coal mined in this manner requires cleaning. In underground mining, the cutting and loading methods used lead to somewhat greater amounts of impurities, and about 67 percent of the coal mined in this manner requires cleaning. Overall, about 49 percent of the coal mined in this country is mechanically cleaned. In 1972, about 355 million metric tons of raw coal were cleaned, yielding about 266 million metric tons of cleaned coal. The amount of coal cleaning showed a net decrease of about 20 percent from 1968 to 1972; this decrease resulted from the increased use of strip mining (which requires less cleaning), and the increased shipments to electric utilities, who usually do not require cleaning. However, the amount of coal cleaning increased by about 8 percent between 1971 and 1972.

Mechanical coal cleaning involves methods similar to those used in the ore-dressing industries. About 96 percent of coal cleaning is done by wet-processing methods, with pneumatic or air cleaning methods being used for the other 4 percent. The dust abatement regulations of the Occupational Health and Safety Act will eventually cause a phasing out of pneumatic cleaning over the next few years.

About 18 percent of the coal which is cleaned by wet-processing methods is thermally-dried before being loaded. Drying is done to avoid freezing problems, to facilitate handling, to improve quality, or to decrease transportation costs. In 1972, there were 112 thermal drying plants in this country which processed about 48 million metric tons of coal. This represents an increase of about 11 percent from the previous year. During the same year the total number of coal cleaning plants decreased from 411 to 408, but the number of coal cleaning plants with driers increased from 103 to 112. In such drying plants, a significant source of pollution is the particulate emissions from the driers. To meet the new regulations on particulate emissions, venturi scrubbers (or the equivalent) must be installed.

The present turmoil in the related areas of energy supply and environmental protection makes the prediction of future growth trends in the coal industry rather uncertain. The basic factor inhibiting the rapid growth of coal production is the high sulfur content of most readily-available Eastern coals. The Western portion of the nation has large reserves of low sulfur coal but the high cost of transporting this coal to the Midwestern and Eastern markets has, at least until recently, precluded large scale use of this source. The alternative to the use of low sulfur coal is flue gas desulfurization technology, and an intensive effort is currently being directed in this area. If the regulations on sulfur dioxide emissions from electrical power plants are adhered to and flue gas desulfurization technology lags, a slowing in the growth rate of coal could result. On the other hand, restrictions on imports of petroleum could accelerate the demand for coal.

Emission Sources and Pollutants. The emissions of primary concern from coal cleaning plants are the particulates resulting from drying operations. The available data indicate that in 1971, only 1 percent of the coal drying capacity was equipped with devices capable of removing at least 99 percent of the particulate matter in the effluent gas. Another 87 percent of the capacity was equipped with low-energy cyclones which remove only about 90 percent of the particulate matter. In order to meet the new regulations, these cyclones will have to be replaced with the high-energy venturi scrubbers.

The uncontrolled emission levels were calculated from the emission factors for coal driers. The emission factors given by the EPA are 5.9 kilograms of particulates per metric ton of coal dried for fluidized bed driers and 2.3 kilogram per metric ton for flash driers. Since the Bureau of Mines data indicate that 64 percent of the coal driers are fluidized bed units and the rest are various designs which should have emissions similar to flash driers, a weighted average emission factor of 4.6 kilogram of particulates per metric ton of dried coal was calculated.

The emissions at the 1972 control level are based on 90 percent particulate removal for 87 percent of the throughput, and 99.5 percent particulate removal for 1 percent of the throughput. In the state-by-state breakdown, this value has little meaning for the states with a small number of plants because in these cases, the extent of control may vary considerably from the national average values used in the calculations.

The "allowable" emissions are the values that apply if all throughput existing before January 1, 1974, just meets the appropriate State Implementation Plan level, and all throughput added after that date just meets the Federal New Source standard. The calculation of the allowable emissions for the plants existing in 1972 is detailed in Table 3-1-1. These emissions were adjusted to 1974 by adding 4 percent per year, which is equivalent to assuming that the growth in throughput over these two years occurred through new plants having the same size distribution as the existing plants. Again, this could be considerably in error for some states but should be quite good for the national total.

Table 3-1-1.

Coal Cleaning Industry Allowable Particulate Emissions

1972 Data

State	No. of Plants	Average Drying Rate		Allowable Particulate Emission	
		1,000 metric ton/yr	kkg/hr	kg/hr/plant	Total metric ton/yr
Alabama	1	1,137	129.8	16.4	158
Colorado	1	294	33.6	13.4	130
Illinois	9	722	82.6	23.2	2,018
Indiana	1	1,213	138.5	23.2	224
Kentucky	15	256	29.1	18.2	2,628
North Dakota	2	74	8.6	8.7	168
Ohio	4	289	33.1	18.2	701
Pennsylvania	13	388	44.5	-	675[1]
Utah	2	327	37.2	-	580[2]
Virginia	10	408	46.8	21.0	2,028
West Virginia	54	448	51.3	21.0[3]	10,951
Totals	112				20,261

[1] 0.2 grains/.03 cubic meter gas

[2] 85% control

[3] Assumed, since no general regulation was included in SIP.

Control Technology and Costs. In most cases, the technology used for removing this particulate matter will be venturi scrubbers. If other technology is used for some of the driers, its cost should be comparable to the cost of venturi scrubbers, so that a cost analysis based on venturi scrubbers should be valid.

A report by the Industrial Gas Cleaning Institute (IGCI) gives some cost information on venturi scrubbers for coal driers. This information and some calculations based on it are summarized in Table 3-1-2. Annualized control costs and industry operating data are detailed in Table 3-1-3.

Table 3-1-2.
Coal Cleaning Industry Unit Cost Data on Wet Scrubbers (In 1973 Dollars)

	Typical Plant 1				Typical Plant 2			
Coal Drying Capacity (MT/Hr)	227				680			
Gas Flow Rate (m^3/min)[1]	5,378				16,134			
Particulate Removal (%)	99.64				99.84			
Operating Cost Components:	No. Units	Cost (1,000 $/yr)			No. Units	Cost (1,000 $/yr)		
		Low	Medium	High		Low	Medium	High
Operating labor	125 hr/yr	0.63	0.88	1.25	125 hr/yr	0.63	0.88	1.25
Maintenance materials		2.39	2.66[2]	2.93		6.47	7.19[2]	7.91
Power	2.45×10^6 kwh/yr	12.26	26.93	49.00	8.13×10^6 kwh/yr	40.65	89.50	162.7
Process water	64.0×10^6 1/yr	2.55	4.24	5.94	193×10^6 1/yr	7.64	12.73	17.83
Total O&M Costs		17.83	34.71	59.12		55.39	110.30	189.69

Basis: Industrial Gas Cleaning Institute report on Contract No. 68-02-0301 for EPA, 9/30/72. Values for two units given were averaged.

[1] At 190°F and 14.16 psia.

[2] Escalated from 1971 to 1973 using CE Plant Cost Index (= 132.2 in 1971; 144.1 in June 1973).

Table 3-1-3.
Coal Cleaning Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (1,000 MT/Hr)	5,650.6	7,218.5	7,399.9

Annual Growth Rate Over the Period 1976-85 = 2.77%

PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Hr)	Pollutants Controlled	Control Technology
Model 1	31.94	Particulates	Venturi Scrubber
Model 2	54.51	Particulates	Venturi Scrubber
Model 3	101.22	Particulates	Venturi Scrubber
Model 1 (new plants)	31.94	Particulates	Venturi Scrubber
Model 2	54.51	Particulates	Venturi Scrubber
Model 3	101.22	Particulates	Venturi Scrubber

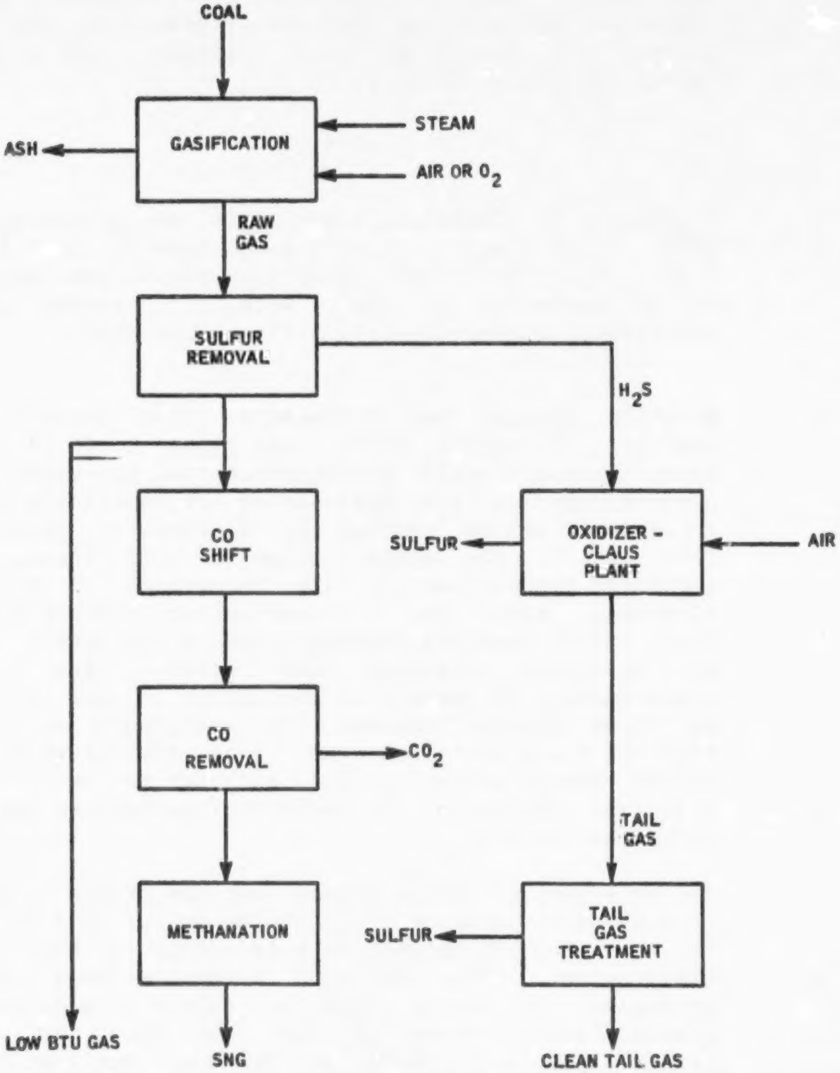
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	56.40	70.21	73.34		
Legislated Controls:					
Particulates	24.93	1.67	1.75		
CONTROL COSTS (Million 1975 $)					
Investment	4.71	0.12	0.26	27.84	13.56
Total Annual	2.52	4.69	4.78	49.72	44.20
Capital	1.68	3.22	3.27	33.82	30.13
O&M	0.84	1.47	1.51	15.90	14.07

COAL GASIFICATION INDUSTRY

Production Characteristics and Capacities. One of the most pressing aspects of the current national energy problem is the present and projected shortage of natural gas. As a result of this shortage, a considerable number of projects are underway involving the manufacture of synthetic natural gas (SNG) from the heavier, more plentiful energy sources. Although SNG could be made from several energy sources, including coal, coke, and petroleum residuum, all of the present commercial plans are based on coal.

For some industrial applications, fuel gases that have a heating value which is considerably less than that of natural gas or SNG can be used. Whereas the primary constituent of natural gas is methane, the primary combustible components of the "low Btu" gases are hydrogen and carbon monoxide (see Figure 3-2-1). Coal gasification processes involve the reaction of coal with steam and oxygen to produce synthetic natural gas. Low Btu gases can be produced by substituting air for oxygen as a reactant.

Figure 3-2-1.
Simplified Flow Diagram of Coal Gasification



NOTE: IN SOME VERSIONS, H_2S AND CO_2 ARE REMOVED TOGETHER AFTER THE CO SHIFT.

Production of both SNG and low Btu gas are expected to be rather extensive by 1985, even though commercial scale operations do not currently exist. However, projections of the amounts of synthetic fuel gases which will be produced at a given time in the future are subject to considerable uncertainty because of the general turmoil in the energy situation. Most plants that are expected to be in commercial operation by 1985 are already in the planning stages, and initial plants are expected to be in operation during the period 1977-78.

A total of 23 plants are expected to be producing SNG by 1985; plant capacities will range from 2.4 to 9.12 million SCM/d. About 46 low Btu production plants are expected to be in operation by 1985, with the average plant size equivalent to approximately 5.47 million SCM/d.

Emission Sources and Pollutants. Coal contains varying amounts of sulfur (from less than 1 to 7 percent). Essentially all sulfur contained in coal is converted into gaseous species (i.e. H_2S) during the gasification process. These gases can be removed by a two-step process which involves (1) the concentration of H_2S through an amine scrubbing process and (2) the conversion of the H_2S to elemental sulfur via a Claus sulfur recovery plant. The Claus sulfur recovery process is currently widely practiced by petroleum refiners and natural gas processers. Approximately 95 percent of the sulfur in coal is removable by Claus plants. However, the remaining 5 percent escapes from the Claus unit (tail gas) in the form of various sulfur oxides (mostly sulfur dioxide) and must be controlled with tail gas scrubbing to reduce sulfur dioxide emissions to acceptable levels.

The emissions of sulfur oxides from the Claus plants were calculated by assuming that all the sulfur in coal goes into the gas and 95 percent of this sulfur is recovered by the Claus plant. The emission factors without tail gas treatment, in metric tons of sulfur dioxide per billion standard cubic meters of gas, are 88.41 for synthetic natural gas and 6.60 for low-Btu gas. The installation of tail gas treatment facilities is assumed to reduce sulfur dioxide emissions by 90 percent.

Control Technology and Costs. It is assumed that the cost of bulk sulfur removal from a coal gasification plant is not a cost associated with the Clean Air Act Amendments of 1970 but is a standard practice partially induced by the byproduct value of elemental sulfur. In other words, even before the 1970 Amendments were passed, coal gasification would have had a Claus plant for bulk sulfur removal. The additional facility which is attributable to the Clean Air Act is the tail gas treatment plant. Since this situation is analogous to that for natural gas plants, the investment and operating costs for tail gas treatment plants were developed based upon the analyses for petroleum refining and natural gas processing.

Since a Claus plant normally recovers about 95 percent of the sulfur fed to it and the tail gas treatment facility recovers about 90 percent, the combined recovery for both units operating together is about 99.5 percent. The credit for the additional sulfur recovered by the tail gas treatment plant is calculated by assuming a price of $10-$15 per ton of sulfur. Recent market analyses indicate that this may be an optimistic assumption.

Investment and annual operating and maintenance costs for selected model-sized coal gasification plants, and total industry costs for controlling sulfur dioxide from plants expected to come on stream between 1977 and 1985 are given in Table 3-2-1.

Table 3-2-1.
Coal Gasification Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (MT/Day)	0	604.4	1,386.3		

Annual Growth Rate Over the Period 1976-85 = 22.6%

PROCESS CHARACTERISTICS	Model Plant Sizes (10^6 SCM/Day)	Pollutants Controlled	Control Technology
SNG	70,210,247	Sulfur Oxides	Claus Plant; Tail Gas Treatment
Low BTU Gas Plants	11.2	Sulfur Oxides	Claus Plant; Tail Gas Treatment

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Sulfur Oxides	0	1.495	4.315		
Legislated Controls:					
Sulfur Oxides	0	1.542	4.456		
CONTROL COSTS (Million 1975 $)					
Investment	-	14.84	11.22	120.32	120.32
Total Annual	-	8.40	26.26	121.24	121.24
Capital	-	3.58	15.82	68.19	68.19
O&M	-	4.82	10.44	53.05	53.05

NATURAL GAS INDUSTRY

Introduction Characteristics and Capacities. The natural gas industry may be viewed as having two major sectors: production and transmission/distribution. The production sector is dominated by large firms, but a large number of smaller firms do contribute a sizable share of the total output. The transportation/distribution sector is primarily organized as public utility companies which operate under Federal and/or state regulations. Although many gas utility companies are now integrating back into production, the basic structure of the industry remains as described here.

As of January 1, 1974, the 763 natural gas processing plants in the United States had a total capacity of 2.11 billion cubic meters per day. The actual production rate of these plants in 1973 was 1.57 billion cubic meters per day. For each of the last two years, the natural gas production rate has decreased slightly. The rate of change in production rate since 1967 has been at an increase of only about 4 percent per year. Most projections of natural gas supply assume little or no increase over the next several years.

The production of petroleum (crude oil) is almost always associated with the production of substantial quantities of natural gas. The distinction between "oil wells" and "gas wells" is an arbitrary one based on the ratio of oil-to-gas produced. Natural gas is primarily methane, but the raw gas contains varying amounts of heavier hydrocarbons and other gases, such as carbon dioxide, nitrogen, helium, and hydrogen sulfide. In order to obtain a natural gas of pipeline quality, much of these undesired components must be removed. The heavier hydrocarbons, which can be conveniently condensed, are combined with the liquid (oil) production and sent to refineries for further processing; the remaining gas is normally purified at the well site.

Emission Sources and Pollutants. Hydrogen sulfide is the impurity of concern from an air pollution standpoint. Because of the corrosive, poisonous, and odorous nature of hydrogen sulfide, only very low concentrations of it are permitted in the natural gas product. Approximately 5 percent of the natural gas produced in the United States requires some form of treatment to remove hydrogen sulfide. The hydrogen sulfide content of natural raw gas varies from trace quantities to over 50 percent by volume.

Although removal of the hydrogen sulfide from natural gas is universally practiced, recovery of the corresponding sulfur in elemental form to avoid air pollution is not universally practiced. In many of the larger operations, Claus plants have been installed for this purpose, but in many plants the hydrogen sulfide is merely incinerated and flared, resulting in emissions of sulfur oxides.

For the natural gas plants which have Claus plants, the source of the sulfur oxides emitted is the Claus plant tail gas. The amount of this emission corresponds to about 6 percent of the sulfur fed to the Claus plant, as estimated from the capacities of the Claus plants associated with natural gas plants. For the natural gas plants which do not have Claus plants, the sources of the sulfur oxides emitted are the flares in which the hydrogen sulfide removed from the gas is burned. The only available estimate of the emission from such plants which was made by EPA in 1972, was 852,000 metric tons of sulfur dioxide per year.

Control Technology and Costs. Because of the severe limitations on the hydrogen sulfide content of pipeline gas, all natural gas processing plants that handle the sour gas already have the amine scrubbing facilities or equivalent to remove it from the raw gas. The technology needed to prevent hydrogen sulfide from causing air pollution consists of:

- A Claus sulfur plant in which the hydrogen sulfide is converted to elemental sulfur.

- Treatment facilities to remove sulfur dioxide from the Claus plant tail gas.

The investment and operating costs for these processes were discussed in the section on refinery fuel gas burning; the credit for the byproduct sulfur obtained with these processes was also discussed in that section.

In 1973, there were 84 Claus plants in the natural gas processing industry. These plants had a total sulfur capacity of 6,249 metric tons per day, and an actual production rate of 2,443 metric tons per day. The gas throughput associated with this sulfur recovery was 36 million cubic meters per day, or only about 2 percent of the total natural gas production.

Annualized control costs and industry quality data are detailed in Table 3-3-1.

Table 3-3-1.
Natural Gas Processing Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (1,000 MT/Yr)	2,606.8	2,736.3	2,949.3

Annual Growth Rate Over the Period 1976-85 = 1.72%

PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Day)	Pollutants Controlled	Control Technology
Model 1	5.88	Sulfur Dioxide	Scrubber
Model 2	34.31	Sulfur Dioxide	Scrubber
Model 3	272.81	Sulfur Dioxide	Scrubber
Model 4	5.88	Sulfur Dioxide	Scrubber and Claus Unit
Model 5	34.31	Sulfur Dioxide	Scrubber and Claus Unit
Model 6	272.81	Sulfur Dioxide	Scrubber and Claus Unit

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Sulfur Oxides	1,348.37	1,468.41	1,536.00		
Legislated Controls:					
Sulfur Oxides	414.83	6.47	6.92		
CONTROL COSTS (Million 1975 $)					
Investment	27.03	4.53	2.21	149.67	51.38
Total Annual	29.16	43.09	46.59	488.79	422.94
Capital	12.86	18.35	19.61	209.73	180.10
O&M	16.30	24.74	26.98	279.06	242.84

FEED MILLS INDUSTRY

Production Characteristics and Capacities. Feed manufacture is the process of converting the grain and other constituents into the form, size, and consistency desired in the finished feed. Feed milling involves the receiving, conditioning (drying, sizing, cleaning), blending, and pelleting of the grains, and their subsequent bagging or bulk loading.

As of July 1, 1974, the number of existing feed mills was estimated at 7,866 plants, with a total capacity of 148 million metric tons per year. For this report, these have been grouped into the size categories as shown in Table 3-4-1.

Table 3-4-1.
Feed Mills Industry Production Capacities

Size Range (metric tons/day	No. Mills	Capacity (million metric tons/year[1])	Total Capacity (%)	Mill Model Size
0-44	4,170	47	31.8	11,271
45-90	2,790	70	47.3	25,090
91-136	623	23	20.9	36,920

[1] Based on operating 40 hours per week and 50 weeks per year.

Emission Sources and Pollutants. The primary emissions from feed manufacture are particulates, especially dust. The factors affecting emissions include the type and amount of grain handled, the degree of drying, the amount of liquid blended into the feed, the type of handling (conveyor or pneumatic), and the degree of control. An indication of the relative ranking of emission sources in a typical feed mill are:

Mill Operations	Particulates Generated(%)
Rail unloading	25
Collectors for product recovery dust control	21
Truck unloading	15
Truck loading (bulk loadout)	11
Bucket elevator leg vents	5
Bin vents	5
Scale vents	3
Grinding system (feeder, spills)	4
Incinerator (Waste paper)	2
Small boiler (oil)	1
Rail car loading (bulk loadout)	1
Miscellaneous (conveying spouts, pellet mills, feeder lines)	7
Total Feed Mill Dust Emission	100

Unloading of bulk incredients is generally acknowledged to be one of the most troublesome dust sources in feed mills. Centrifugal collectors used for product recovery and dust control represent the second largest emission source.

Factors affecting emission rates from the ingredient receiving area of a feed mill include the type of grain and other ingredients handled, the methods used to unload the ingredient, and the configuration of the receiving pits.

Control Technology and Costs. It is estimated that 88.1 percent of the volume handled in pellet-cooler operations and 56 percent of the volume handled in griding operations have some type of emission control, largely the use of cyclones. In receiving, transfer, and storage operations, roughly one-third of the total volume is controlled by either cyclones or fabric filters, while shipping has only a few installations that have installed controls.

Table 3-4-2 shows the estimated sales, capacity, and emissions for the feed mills industry up to the year 1985. The table also shows the costs of controls on an annualized, investment and cash requirements basis.

Table 3-4-2.
Feed Mills Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (Million MT/Yr)	143.99	166.14	193.10

Annual Growth Rate Over the Period 1976-85 = 3.50%

PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Day)	Pollutants Generated	Control Technology
Feed Mills	40,90,140	Particulates	Fabric Filter

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	1,024.48	1,192.54	1,353.32		
Legislated Controls:					
Particulates	423.55	24.54	27.87		
CONTROL COSTS (Million 1975 $)					
Investment	395.54	81.76	38.13	2,077.58	941.70
Total Annual	204.04	342.73	382.88	3,795.93	3,348.18
Capital	149.34	247.99	273.15	2,737.18	2,411.26
O&M	54.71	94.74	109.73	1,058.76	936.91

KRAFT PULP INDUSTRY

Production Characteristics and Capacities. The kraft pulp industry process mill size distributions are shown in Table 3-5-1. Control cost estimates are based on the "model plant" range size of 454, 907, and 1,361 ADMT/day.

Table 3-5-1
Kraft Pulp Mill Size Distributions

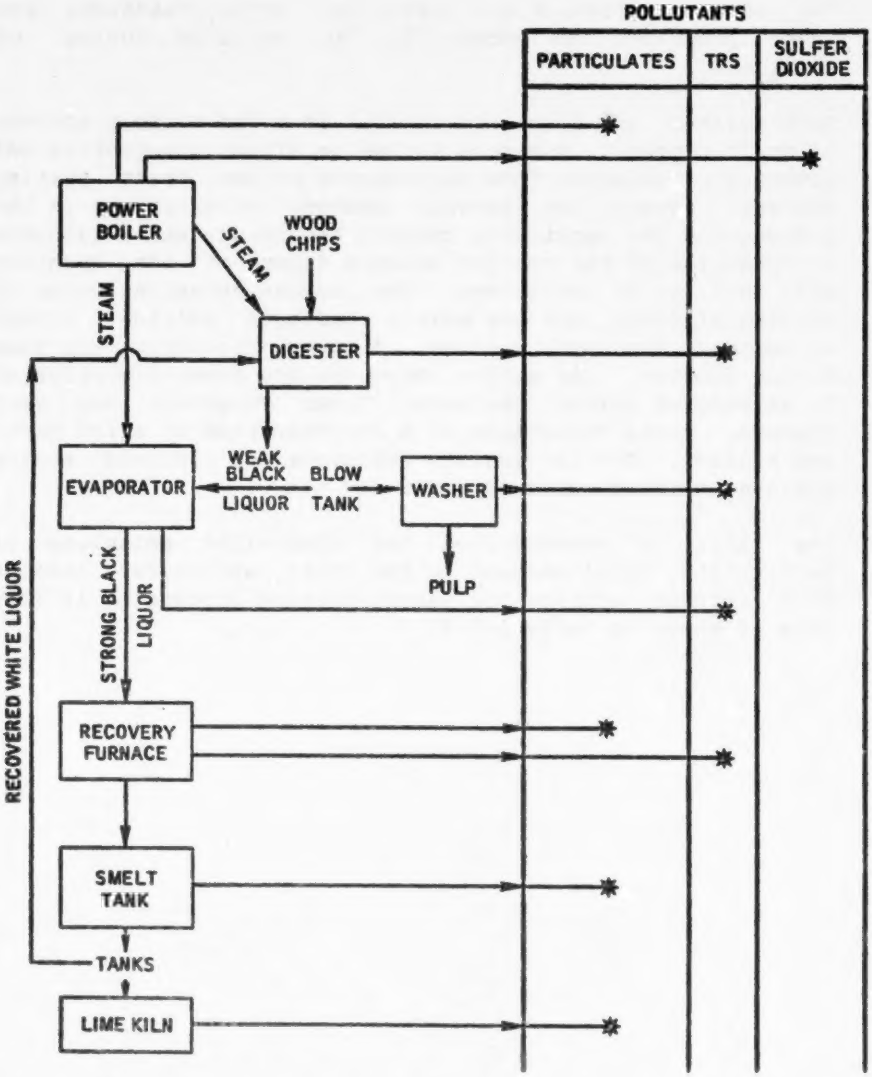
Range of Mill Capacities (ADMT/day)	Number of Mills	Total Cap. of Mills in Size Range 8ADMT/day)	Average Mill Capacity (ADMT/day)	Model Mill Capacity (ADMT/day)
0.770	71	31,809	448.0	454
771-1088	29	24,675	850.9	907
1089-2359	25	33,736	1349.4	1361

Sources: Publishing Co., Inc. "Lockwood's Directory of the Paper and Allied Trades", 97th Edition, New York, 1973; Paper Processing, August, 1974, p.36; Pulp and Paper, "Profiles of the North American Pulp and Paper Industry", June 30, 1974, p.27.

Conventional kraft pulping processes are highly alkaline in nature and utilize sodium hydroxide and sodium sulfide as cooking chemicals. One modification used for the preparation of highly purified, or high-alpha cellulose, pulp utilizes an acid hydrolysis of the wood chips prior to the alkaline cook; this is the prehydrolysis kraft process. Kraft processes enjoy the advantages of being applicable for nearly all species of wood and of having an effective means of recovery of spent cooking chemicals for reuse in the process.

Kraft pulping, in simplified terms, consists of seven separate processes, as shown in Figure 3-5-1. The digesting liquor in this process flow is a solution of sodium hydroxide and sodium sulfide. The spent liquor (black liquor) is concentrated, then sodium sulfate is added to make up for chemical losses, and the liquor is burned in a recovery furnace, producing a smelt of sodium carbonate and sodium sulfide. The smelt is dissolved in water to form green liquor, to which is added quicklime to convert the sodium carbonate back to sodium hydroxide, thus reconstituting the cooking liquor. The spent lime cake (calcium carbonate) is recalcined in a rotary lime kiln to produce quicklime (calcium oxide) for recausticizing the green liquor.

Figure 3-5-1.
Kraft Pulp Mills Production Processes



Included in the uses of kraft pulp are the production of linerboard, solid-fiber board, high-strength bags, wrapping paper, high-grade white paper, and food-packaging materials.

Emission Sources and Pollutants. Main emission sources in the kraft process are the recovery furnace, lime kiln, smelting dissolving tank, and the power boilers. The kraft pulping economics depend upon reclamation of chemicals from the recovery furnace and lime kiln. Hence, emissions from these processes are controlled to minimize losses of chemicals.

Particulates and gases are emitted from the various sources of kraft process. Numerous variables affect the quality and quantity of emission from each source of the kraft pulping process. There are several sources of emissions in the process and the applicable control technology and attainable efficiencies of the control methods depend on the quantity and quality of emissions. The gaseous emissions occur in varying mixtures, and are mainly hydrogen sulfide, methyl mercaptan, dimethyl sulfide, dimethyl disulfide, and some sulfur dioxide. The sulfur compounds are generally referred to as reduced sulfur compounds. These compounds are very odorous, being detectable at a concentration of a few parts per billion. The particulate emissions are largely sodium sulfate, calcium compounds, and fly ash.

The rates of uncontrolled and controlled emissions of particulate, total reduced sulfur (TRS), and sulfur dioxide from various sources of kraft pulping processing in 1974 were as shown in Table 3-5-2.

Table 3-5-2.
Rates of Emissions from Kraft Process

Uncontrolled

Process	Particulates (kg/ADMT)	TRS (kg/ADMT)	Sulfur Dioxide (kg/ADMT)
Digester	0.0	0.72	Trace
Washer	0.0	0.05	Trace
Multiple Effect Evaporator	0.0	0.18	Trace
Recovery Furnace	60.0	2.95	1.2
Smelt Tank	7.8	0.05	Trace
Lime Kiln	34.0	0.22	Trace
Power Boiler[1]	35.3	0.0	19.7
Totals	137.1	4.17	20.9

Controlled

Digester	0.0	Trace	Trace
Washer	0.0	Trace	Trace
Multiple Effect Evaporator	0.0	Trace	Trace
Recovery Furnace	2.00	0.25	1.2
Smelt Tank	0.25	Trace	Trace
Lime Kiln	0.50	Trace	Trace
Power Boiler	2.47	0.0	10.5
Totals	5.22	0.25	11.7

[1] Fuel requirement = 3.09 x 10^7 Btu/ADMT. Coal provides 35%, oil 27%, gas 26%, and bark/wood 12% of the energy. Heating values = coal 13,000 Btu/lb, oil 150,000 Btu/ft^3, and bark/wood 4,500 Btu/f^3. Sulfur content = coal 1.9% and oil 1.8%. Ash content = coal 8.1% and bark/wood 2.9%.

The process weight-emission limitation concept is considered unapplicable to chemical pulping because the nature and size range of particulates, as well as the characteristics of the processes, are vastly different. Provisions of the Washington and Oregon Regulations applicable to pulp mills are used in this report. The regulations include the following control provisions:

1. Total reduced sulfur (TRS) compounds from the recovery furnace: No more than 1 kg/ADMT (1972) reduced to no more than 0.25 kg/ADMT by 1975.

2. Noncondensible gases from the digesters and multiple effect evaporators: Collected and burned in the lime kiln or proven equivalent.

3. Particulates from the recovery furnace: No more than 2 kg/ADMT.

4. Particulates from the lime kiln: No more than 0.5 kg/ADMT.

5. Particulates from smelt tank: No more than 0.25 kg/ADMT.

6. Emissions from power boiler will meet the Federal emission standard.

Control Technology and Costs. The cost estimates for kraft pulping take into account the costs associated with each constituent process. The mill size categories, emissions, and control technologies that have been assumed for each process are shown in Table 3-5-3. This table also presents the total annual emissions and costs estimated for the kraft pulping industry in 1975, 1980, and 1985. The estimated costs of air pollution control are significantly higher than previous estimates because the costs to control TRS and sulfur dioxide were not estimated earlier.

Table 3-5-3.
Kraft Pulp Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (1,000 ADMT/Yr)	84,920	108,870	128,670

Annual Growth Rate Over the Period 1976-85 = 5.06%

(These are sequential processes; that is, a unit of pulp must go through each of these processes to be manufactured.)

PROCESS CHARACTERISTICS	Model Plant Sizes (ADMT/day)	Pollutant Controlled	Control Technology
Digester	454;907;1,361	TRS	Incinerate in Lime Kiln
Stock Washer		TRS	Incinerate in Recovery Furnace
Evaporator		TRS	Incinerate in Lime Kiln
Recovery Furnace		TRS, Particulates	ESP & Venturi Scrubber
Smelt Tank		Particulates	Orifice Scrubber
Lime Kiln		Particulates	Venturi Scrubber
Power Boiler		Particulates, Sulfur Dioxide	ESP & Double Alkali Scrubber

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	518.53	715.19	842.62		
Sulfur Oxides	35.43	48.87	57.58		
Legislated Controls:					
Particulates	263.23	122.01	143.74		
Sulfur Oxides	35.80	48.84	57.54		
CONTROL COSTS (Million 1975 $)					
Investment	420.12	85.72	48.62	2,842.13	1,313.41
Total Annual	394.36	718.72	821.18	7,795.90	6,919.16
Capital	187.47	328.66	361.37	3,542.82	3,117.88
O&M	206.89	390.06	459.81	4,253.08	3,801.29

NEUTRAL SULFITE SEMICHEMICAL PAPER INDUSTRY

Production Characteristics and Capacities. The size distribution of neutral sulfite semichemical (NSSC) pulp mills is classified into three size ranges: 0-181, 182-363, and 364-635 air-dried metric tons (ADMT) of air-dried pulp per day. The number of plants in each size range and their capacities are:

Capacity Range (ADMT/day)	No. Mills	Capacity (ADMT/day)	Average Mill Capacity (ADMT/day)	Model Mill Capacity (ADMT/day)
0 - 181	23	2,488	108	113
182 - 363	24	5,455	227	277
364 - 635	8	3,376	422	454

Sources: Paper Processing, August 1974; p.36; Hendrickson, E.R., Roberson, J.E., and Koogler, J.E., "Control of Atmospheric Emissions in the Wood Pulping Industry", PB-190352, Environmental Engineering, Inc. and J.E. Sirrine Company, March 15, 1970.

Semichemical pulps are produced by digesting with reduced amounts of chemicals, followed by mechanical treatment to complete the fiber separation. The most prevalent semichemical pulping process is the neutral sulfite semichemical process. In this process, sodium sulfite in combination with sodium bicarbonate, or ammonium sulfite buffered with ammonium hydroxide, are used as cooking chemicals. These cooks are slightly alkaline in contrast to the highly alkaline kraft, and highly or moderately acidic sulfite cooks. The semichemical pulping processes are used for production of high yield pulps ranging from 60 to 85 percent of dry wood weight charged to the digestion vessel, and can include kraft and sulfite processes suitably modified to reduce pulping action in order to produce higher-than-normal yield pulps.

Semichemical pulps are used in the preparation of corrugating medium, coarse wrapping paper, linerboard, hardboard, and roofing felt, as well as fine grades of paper and other products.

Emission Sources and Pollutants. Discussions and calculations of air emissions from the NSSC process are limited to particulate and sulfur dioxide. The used cooking liquors are discharged to sewers or in some cases they are evaporated and cross-recovered with an adjacent kraft mill or treated in a fluidized-bed system. In this study, the fluidized-bed combustion was assumed for the liquor treatment.

Control Technology and Costs. This report assumed that particulate emissions from the recovery furnace and power boilers burning coal and bark/wood, and sulfur dioxide emission from power boilers burning high sulfur coal and oil were subject to control. To meet the particulate emissions standard from recovery furnaces, a control efficiency of at least 90 percent is required for the control system. A sodium-based, double alkali system was assumed for the control of sulfur dioxide from coal and oil burning power boilers.

Control methods for new plants were selected as follows:

Process	Pollutant	Control Methods
Recovery Furnace	Particulate	Electrostatic Precipitator
Power Boiler	Particulate	Electrostatic Precipitator
	Sulfur Dioxide	Double alkali

All new plants were assumed to be in the 364 to 635 ADMT/day capacity range.

Table 3-6-1 shows the estimated future capacity and process characteristics of NSSC pulp mills. The emissions statistics are also shown, along with annual investment and cost estimates.

The costs estimated in this report are nearly ten times those reported earlier since previous estimates did not include the cost of controlling sulfur oxides.

Table 3-6-1.
Neutral Sulfite Semichemical Paper Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (Million ADMT/Yr)	4.06	5.19	6.09

Annual Growth Rate Over the Period 1976-85 = 4.93%

PROCESS CHARACTERISTICS	Model Plant Size (1000 ADMT/year)	Pollutants Controlled	Control Technology
Boiler	38, 80, 150	Particulates, Sulfur Dioxide	ESP, Double Alkali
Recovery Furnaces	38, 80, 150	Particulates	ESP

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	21.60	29.77	34.86		
Sulfur Oxides	2.12	2.93	3.43		
Legislated Controls:					
Particulates	9.17	0.98	1.14		
Sulfur Oxides	2.15	2.94	3.43		
CONTROL COSTS (Million 1975 $)					
Investment	8.45	14.78	8.88	313.49	130.10
Total Annual	54.33	91.42	105.53	1,012.11	885.17
Capital	24.57	37.94	44.57	431.00	367.73
O&M	29.76	53.48	60.96	581.12	517.44

PRINTING INDUSTRY

Production Characteristics and Capacities. Six major types of printing establishments were considered in this report: book printing and publishing; commercial printing by letterpress; commercial printing by lithography; and commercial printing by gravure. Newspapers were excluded because inks containing little, if any, volatile solvents are employed. Nearly 27,000 establishments comprise the six groups; 80 percent of these are small, employing fewer than 20 people.

Estimates of air pollution abatement costs were based on the application of controls (thermal incinerators) by the 50 largest establishments in each of the first five categories. Perodical and book plants accounted for about 70 percent of the annual volume of ink consumed, which amounted to about 18 million kilograms per year or 181.6 kilo-kilograms per plant annually.

Both commercial letterpress and lithography represent a large number of smaller establishments, about 13,000 and 8,000 facilities, respectively. While the 50 largest establishments in each of the categories comprise only 40 percent and 25 percent of the annual volume of ink consumed, respectively, they tend to use web-processing techniques exclusively, which are a primary contributer to hydrocarbon emissions. Virtually all volatile components (approximately 40 percent by weight) of the ink are driven off during the drying or curing stage of the web printing process.

All commercial gravure printers also use the web printing methods. There were 127 establishments in 1972 representing about 114 million kilograms of ink usage.

In summary, cost estimates were derived on the basis of applying controls to 327 establishments corresponding to an average plant size of 499 metric tons of ink consumed per year.

Emission Sources and Pollutants. Atmospheric hydrocarbon emissions associated with printing are attributable to the volatile organic components of the various types of inks employed. The volatile content ranges from about 40 percent (heat-set letterpress, lithographic, and screen process inks) to more than 60 percent for flexographic and gravure. The percentage of the volatile content released to the atmosphere can vary widely in the absence of controls. For purposes of this report, full volatilization is assumed without control. On this basis, an average-sized establishment that consumes approximately 499 metric tons of ink annually will generate about 204 metric tons of hydrocarbon emissions per year.

Control Technology and Costs. Suitable controls (thermal incinerators) provide about 95 percent removal efficiency. Thermal incineration with heat exchange units could be employed to achieve desired levels of hydrocarbon emission control. Although carbon absorption techniques present advantages because of the possibility of solvent regeneration, they are difficult to apply to printing because inks often consist of a mixture of volatile solvents, making subsequent separation steps necessary.

Capital and annual operating and maintenance costs were estimated on the basis of applying a control unit designed to handle approximately 109 kilograms of hydrocarbon emissions per hour (or about 227 metric tons per year). Installation and equipment, including heat exchanger, are approximately $70,000 for such a unit. Operating costs are about $16,000 per year. Annualized control costs and industry operating statistics are detailed in Table 3-7-1.

Table 3-7-1.
Printing Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (1,000 MT/Yr)	177.42	223.39	264.15

Annual Growth Rate Over the Period 1976-85 = 5.12%

PROCESS CHARACTERISTICS	Model Plant Sizes (Metric Tons)	Pollutants Controlled	Control Technology
Commercial Printing - Letterpress and Lithography	550	Hydrocarbons	Thermal Incinerators

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Hydrocarbons	99.36	137.23	161.91		
Legislated Controls:					
Hydrocarbons	100.11	136.90	8.08		
CONTROL COSTS (Million 1975 $)					
Investment	5.15	2.72	0.94	44.03	21.51
Total Annual	6.60	11.74	13.47	126.39	111.36
Capital	3.67	6.40	7.17	68.71	60.14
O&M	2.94	5.34	6.31	57.67	51.22

CHLOR-ALKALI MERCURY CELLS INDUSTRY

Production Characteristics and Capacities. High-purity caustic soda and chlorine are coproducts in the electrolytic process which uses flowing mercury metals as a moving cathode. The caustic soda product finds major markets in those chemical manufacturing operations where high-purity and freedom from sodium chloride and metal impurities are in demand. Of the two basic processes, e.g., mercury cell and diaphragm cell for producing chlorine, only the one employing the mercury cell results in mercury emissions. Chlorine is produced almost entirely by the electrolysis of fused chlorides for aqueous solutions of alkali-metal chlorides. Chlorine is produced at the anode, while hydrogen and potassium hydroxide or sodium hydroxide derive from processes taking place at the cathode. Anode and cathode products must be separated, such as in a cell which employs liquid mercury metal as an intermediate cathode.

The use of the mercury cell in the United States has grown from 5 percent of the total installed chlorine capacity in 1946 toward a maximum of 28 percent of the installed chlorine capacity through 1968. The 1974 capacity was estimated at 7,863 metric tons of chlorine per day at 31 plants. However, since then, the number of operating plants has been decreasing. The size distribution of these plants is given below:

Number of Plants	Capacity Range (Chlorine Production) Metric Tons/Day
5	0 - 90.7
10	90.8 - 181
8	182 - 272
5	273 - 454
3	455 - 580
31	

Emission Sources and Pollutants. The major sources of direct emissions of mercury to the atmosphere are the hydrogen by-product stream, end-box ventilation system, and cell-room ventilation air. The minimum known treatment of the byproduct hydrogen gas that leaves the decomposer consists of cooling the stream to 110°F followed by partial removal of the resulting mercury mist. For hydrogen saturated with mercury vapor at this temperature, the daily vapor loss is estimated to be 3.4 kg of mercury vapor per 100 metric tons of chlorine produced. The entrainment of condensed mercury in the hydrogen stream will result in additional emissions. The estimated uncontrolled emission of mercury vapor and mercury mist, after minimum treatment has occurred, is estimated to be up to 25 kg per 100 metric tons of chlorine produced.

Mercury vapor and mercury compounds are collected from the end-boxes, the mercury pumps, and the end-box ventilation system. Preliminary results of source testing by EPA indicate that the mercury emissions from an untreated or inadequately treated end-box ventilation system range from 1 to 8 kg per 100 metric tons of chlorine produced.

In addition to cooling the cell room, the cell-room ventilation system provides a means of reducing the cell-room mercury-vapor concentration to within the recommended Threshold Limit Value (TLV) for human exposure to mercury vapor. On the basis of data obtained from operating plants, it has been estimated that mercury emissions from the cell-room ventilation system vary from 0.2 to 2.5 kg per day per 100 metric tons of daily chlorine capacity, assuming a concentration equal to the TLV of 50 micrograms per cubic meter of ventilation air.

The Environmental Protection Agency has estimated that uncontrolled emissions from the production of chlorine in mercury cells averages approximately 20 kg of mercury per 100 metric tons of chlorine produced.

Control Technology and Costs. Control technologies and cost estimates are based on the consideration that the maximum daily mercury emission from any single site shall not exceed 2,300 grams; this assumption is in compliance with the National Emissions Standards for Hazardous Air Pollutants promulgated by EPA. Control techniques applicable to the hydrogen gas stream include: cooling, condensation, and demisting; depleted brine scrubbing; hypochlorite scrubbing; absorption on molecular sieve; and adsorption on treated activated carbon.

With appropriate modification, the control techniques applicable to the end-box ventilation stream include cooling, condensing, and demisting; depleted brine scrubbing; and hypochlorite scrubbing. It is judged that the molecular-sieve adsorption system will become applicable in the near future to the end-box ventilation-gas stream. This control technique will permit compliance with the hazardous emission standard.

Mercury vapor from the cell-room ventilation air can be minimized by strict adherence to recommended good housekeeping and operating procedures. No other control technique is commercially tested at this time. All mercury emissions could be eliminated by the conversion of mercury-cell plants to the use of diaphragm cells plus a special caustic soda purification system. Such conversion is presently judged to be an unacceptable alternative due to the very high estimated cost. Control costs were estimated on a plant-by-plant basis. Investment per plant ranges from $123,000 to just over $1.3 million, depending on capacity and operating characteristics. Annualized control costs and industry statistics are detailed in Table 3-8-1.

Table 3-8-1
Chlor-Alkali Mercury Cell Industry Data Summary

ACTIVITY LEVEL		1975	1980	1985		
Capacity (MT/Day)		7,447	7,986	7,489		
Annual Growth Rate Over the Period 1976-85 = 1.59%						
PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Day)		Pollutants Controlled		Control Technology	
Mercury Cell Electrolysis	232		Gases & Mists		Scrubbing	
EMISSIONS (MT/Yr)		1975	1980	1985	1971-85	1976-85
1971 Controls:						
Mercury Gases & Mists		10.58	12.70	11.85		
Legislated Controls:						
Mercury Gases & Mists		5.30	1.74	1.63		
CONTROL COSTS (Million 1975 $)						
Investment		4.79	0.42	0	28.26	12.09
Total Annual		5.52	10.05	9.75	104.98	92.23
Capital		2.63	4.57	4.60	48.60	42.38
O&M		2.89	5.48	5.15	56.38	49.85

NITRIC ACID INDUSTRY

Production Characteristics and Capacities. Nitric acid is used in the manufacture of ammonium nitrate and in numerous other chemical processes. Ammonium nitrate, which is used as both a fertilizer and in explosives, accounts for about 80 percent of the nitric acid consumption. Nitric acid is produced by oxidation of ammonia, followed by absorption of the reaction products in dilute acid solution. Most nitric acid plants in the United States are designed to manufacture acid with a concentration of 55 to 65 percent, which may subsequently be dehydrated to produce 99 percent acid.

At the beginning of 1974, 46 privately-owned companies operated 76 nitric acid plants in the contiguous 48 states, in addition to seven plants operated for the U.S. Government by five companies. These government-owned plants are included in cost estimates as part of the nitric acid industry by inflating the private costs by 10 percent. Nearly all nitric acid produced in the United States is for domestic consumption.

Emissions Sources and Pollutants. Nitrogen oxides, the primary pollutants of concern in the production of nitric acid, are emitted in the tail gas from the absorption tower. Numerous variations on the basic nitric acid production process affect both the emissions and the difficulty of control. Two of the more important variables are the amount of excess oxygen present in the absorption tower and the pressure under which the absorption tower operates. Many plants practice partial pollution abatement (decolorization) in accordance with local regulatory agencies. Under this practice, the highly visible reddish-brown nitrogen dioxide is reduced to colorless nitric oxide. Although visible emissions are reduced, the practice does nothing to prevent emission of nitrogen oxides to the atmosphere.

Emissions from nitric acid plants consist of the oxides of nitrogen in concentrations of about 3,000 ppm nitrogen dioxide and nitric oxide, and minute amounts of nitric acid mist. Emissions from nitric acid plants are typically in the order of 22 kg nitrogen oxides per metric ton of 100 percent acid produced.

Control Technology and Costs. Catalytic reduction with natural gas is a feasible and proven control technology used in nitric acid plants both here and abroad. The absorber tail gas is mixed with 38 percent excess natural gas and passed over a platinum or palladium catalyst. Catalytic reduction with ammonia or hydrogen has the advantage of being selective in the sense that only the nitrogen oxides are reduced. In addition to higher costs, reduction with ammonia requires close temperature control to prevent the reformation of nitrogen oxides at higher temperatures or the formation of explosive ammonium nitrate at lower temperatures.

Table 3-9-1 shows the estimated future sales, capacities, and outputs for the nitric acid industry. Also shown in the table are the reductions in nitrogen oxide emissions for the selected years, and the three major cost categories: annualized, investment, and cost requirements.

Table 3-9-1.
Nitric Acid Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985	1971-85	1976-85
Capacity (1,000 MT/Day)	25.17	34.09	40.79		
Annual Growth Rate Over the Period 1976-85 = 5.11%					
PROCESS CHARACTERISTICS	Model Plant Sizes (1,000 MT/Day)		Pollutants Controlled		Control Technology
Ammonia Oxidation	141.2;361.1;571.7; 940.0		Nitrogen Oxides		Catalytic Reduction
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Nitrogen Oxides	143.17	193.02	232.18		
Legislated Controls:					
Nitrogen Oxides	65.04	15.04	18.12		
CONTROL COSTS (Million 1975 $)					
Investment	16.00	4.53	2.33	80.28	37.76
Total Annual	15.15	27.59	32.48	300.10	270.61
Capital	6.64	10.92	12.37	119.79	107.00
O&M	8.51	16.67	20.11	180.31	163.61

PAINT MANUFACTURING INDUSTRY

Production Characteristics and Capacities. The manufacturing of paints involves the mixing or dispersion of pigments in oil, resin, resin solution or latex at room temperature. Mixing is then followed by the addition of specified proportions of organic solvents or water to obtain the desired viscosity.

In 1972, there were 1,556 plants manufacturing paint products in the United States. Production is not divided evenly, with approximately 30 percent of the plants accounting for nearly 90 percent of production.

The average-sized plant accounts for about 6.06 million liters per year or roughly 22,740 liters per day. The balance of the plants were omitted from control cost considerations because they collectively account for only about 379 million liters per year, or about 7 percent of the daily production of the average plant in the larger category.

Current trends in the industry should decrease the future hydrocarbon emission levels associated with paint manufacturing. These include the use of water-based paints and new application techniques such as powder coating. These developments will continue to have a negative impact on the demand for organic solvent-based paints; it is estimated that water-based paints currently represent about 25 percent of total production volume.

Emission Sources and Pollutants. Air pollutants from paint manufacturing are hydrocarbons originating from organic solvents and particulates from paint pigments. About 908 grams of particulates are emitted per metric ton of pigment dispersed. Hydrocarbon emission estimates assume that 75 percent of the 1975 volume of paint was solvent based.

Control Technology and Costs. Control of hydrocarbon emissions from paint production can be accomplished by these methods: flame combustion, thermal combustion, catalytic combustion, and absorption. Thermal combustion (with heat exchange) is considered the most feasible method of control; equipment incorporating heat exchange devices was chosen because of current anticipated future fuel shortages and assumed removal efficiences of 95 percent. Catalytic combustion units, while highly promising from the standpoint of lower fuel requirements (but higher initial investment costs), still present technical operating problems. Baghouses (fabric filters) are suitable for control of particulate emissions from pigments; particulate removal efficiences of more than 95 percent are readily achieved.

Estimates for air pollution control for the total industry were based on assumed compliance by plants averaging about 7.58 million liters of paint production per year; fewer than 500 plants of this capacity were assumed to be in operation. Future cost predictions are complicated by the emergence of technological trends away from the use of solvent-based paints. Annualized control costs and production statistics are detailed in Table 3-10-1.

Table 3-10-1.
Paint Manufacturing Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (Million Liters/Day)	11.05	11.32	11.56

Annual Growth Rate Over the Period 1976-85 = 1.30%

PROCESS CHARACTERISTICS	Model Plant Sizes (Liters/Day)	Pollutants Controlled	Control Technology
Paint Production	22,740	Hydrocarbons	Thermal Incinerator
Paint Production	22,740	Hydrocarbons	Scrubber

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Hydrocarbons	908.48	1,104.06	1,150.33		
Legislated Controls:					
Hydrocarbons	931.94	1,113.98	1,152.62		
CONTROL COSTS (Million 1975 $)					
Investment	6.81	1.35	0	34.40	11.78
Total Annual	8.29	12.33	12.75	137.94	119.36
Capital	3.68	5.33	5.60	59.99	51.73
O&M	4.61	6.99	7.14	77.95	67.64

PHOSPHATE FERTILIZER INDUSTRY

Production Characteristics and Capacities. The major end products of the phosphate fertilizer industry are ammonium phosphates, triple superphosphate, normal superphosphate, and granular mixed fertilizers. Phosphoric acid and superphosphoric acid are intermediate products.

All phosphate fertilizers are processed from ground phosphate rock treated with sulfuric acid to produce either normal superphosphate or wet-process phosphoric acid. A phosphoric acid intermediate may then be reacted with ammonia to produce diammononium phosphate and other ammonium phosphates, or reacted with ground phosphate rock to manufacture triple superphosphate. Superphosphoric acid, produced by dehydration of wet-process phosphoric acid, is used in preparing some mixed fertilizers. Granular mixed fertilizers are made from either normal superphosphate or triple superphosphate, with ammonia and potash. Bulk-blended mixed fertilizers are manufactured by physically mixing particles of other fertilizer components and liquid mixed fertilizers. Bulk blends and liquids are not major sources of air pollution and are not considered in estimating the industry abatement cost.

The phosphate fertilizer industry is characterized by a number of large, modern efficient plants located near the source of raw materials. In general, these plants manufacture the more concentrated forms of fertilizer, diammonium phosphate (DAP) and triple superphosphate (TSP). These industries are particularly concentrated in Florida.

Smaller plants, located near the retail markets, manufacture the less concentrated forms: granulated mixed fertilizer (NPK) and normal superphosphate (NSP). The smaller NSP, NPK, and bulk-blend plants are located in the farming states. At the beginning of 1973, there were 33 DAP plants, 13 TSP plants, 45 NSP plants, and 344 ammoniation-granulation (NPK) plants. In addition, about 5,000 bulk-blending plants were operating in 1973.

Due to the seasonal demand for fertilizer, many plants manufacturing NSP and NPK operate only a portion of the year. In contrast, those plants manufacturing DPA and TSP generally operate year-round.

Emission Sources and Pollutants. Emissions from phosphate fertilizer processing plants are mainly fluorides (in the form of hydrogen fluoride and silicon tetrafluoride) and particulates. Fluorides are generated in the processes of acidulation of phosphate rock which contains calcium fluoride.

In the phosphate fertilizer industry, particulate emissions of significance originate from: phosphate rock grinding; calcination, drying, and transfer processes, triple superphosphate manufacture; ammonium phosphate production; normal superphosphate manufacture; and NPK bulk-blending and granulation plants.

In phosphate rock processing, particulate emissions are issued from the calcination, drying, grinding, and transfer processes. The emission factors for these processes are 7.5, 10, and 1 kg per metric ton of rock, respectively.

In granular triple superphosphate production, particulate emissions may originate from a number of points in the process. Most of the particulates are given off in the drying and product-classification processes. The off-gas from the reactor (in which phosphate rock is acidulated with phosphoric acid) and the blunger (in which the reactor effluent is mixed with recycled product fines to produce a paste) may account for a considerable percentage of the total particulates emitted.

Particulate emissions from diammonium phosphate manufacture originate mainly from the granulator and the dryer. It has been estimated that the total emissions amount to approximately 20 kg per metric ton of product from both sources.

Emissions from the manufacture of run-of-pile normal superphosphate originate from both the acidulation and "denning" processes. Although the emission factors for particulates are not known, they are estimated to be in the order of 5 kg per metric ton.

The NPK or granulation plants manufacture a variety of products. Many different emission factors probably will apply for this class of fertilizer plant. In fixing the emission factors, these plants are assumed to employ an ammoniation-granulation process similar to that used in the DAP process, or approximately 20 kg of particulates per metric ton of product.

The emission factors for particulates are high in the triple superphosphate, diammonium phosphate, and NPK plants. The bulk of these emissions in all three processes originates from the granulation process. There is a strong economic incentive to reduce these emissions since they contain valuable products and in many cases are associated with ammonia vapors (from the ammoniation process), whose recovery is an economic necessity.

Control Technology and Costs. Most of the phosphate rock of higher available phosphorus pentoxide content is ground and beneficiated to enhance its reactivity and to eliminate some of the impurities. The particulate emissions from the grinding and screening operations may be effectively controlled by employing baghouses in which the dust is deposited on mechanically-cleaned fabric filters. The dust-laden gas from the rock-drying (and perhaps defluorination) operations may first pass through a cyclone and then through a wet scrubber (such as a venturi). The efficiency of this combination should be better than 99 percent.

Particulate and fluoride emissions from phosphate fertilizer plants traditionally have been removed from waste gaseous streams by wet scrubbing. While efforts have been directed at removing fluorides, up to 99 percent of the particulates are simultaneously removed. Wet scrubbers of varying efficiencies have been used for this double purpose. The fluoride and particulate-laden scrubber water is usually disposed of in a gypsum pond.

For control of particulate emissions from granular TSP plants, various wet scrubbers will be provided for a number of gaseous waste streams. The effluent from the reactor-granulator will be scrubbed in two stages. The first stage will be a cyclone and the second a cross-flow packed scrubber. The gases from the drier and cooler will be scrubbed in venturi-type packed scrubbers. Waste gases from storage of the granular product are usually scrubbed in a cyclone scrubber, although some plants use packed scrubbers. The scrubbing liquid used in all scrubbers will be recycled pond water except for the first-stage scrubbing of gases from the reactor granulator, where weak phosphoric acid will be used and recycled to the reactor.

In DAP plants, control of particulates will be achieved for gaseous streams originating from the reactor granulator, the drier, and the cooler, together with combined gaseous streams ventilating such solids-processing equipment as elevators, screens, and loading and unloading. Two-stage scrubbing will be employed for each of the streams listed. The first stage will consist of a cyclone scrubber; the scrubbing medium will be diluted (30 percent) phosphoric acid for purposes of recovering ammonia and the product. Most of the particulate matter will be removed in the first stage, and the balance will be removed in the second stage consisting of a cross-flow packed scrubber in which recycled pond water is used as the scrubbing medium.

It is assumed that only run-of-pile normal superphosphate is produced in NSP plants. A cyclone scrubber will be employed in removing particulates in gaseous streams originating from the reactor-pugmill, den, and curing operations.

An ammoniation-granulation process is assumed for NPK plants. Cyclones will be installed ahead of primary scrubbers. The primary scrubber (typically employing dilute phosphoric acid as a scrubbing medium) is considered an integral part of the process in which valuable reactants (ammonia) and the product are recovered.

Cross-flow scrubbers have been used in estimating costs of controlling emissions of both particulates and fluorides. Most of the control technologies described above have been applied for more than a decade. Wet scrubbers of varying efficiencies have been integral parts of many phosphate fertilizer processes. The collection of waste gaseous streams and the removal of fluorine compounds from these streams has long been practiced to protect the health and safety of process operating personnel. Collection of particulate materials from those waste gaseous streams is dictated by economic necessity because valuable products are involved.

Table 3-11-1 shows the estimated future sales and capacities for phosphate fertilizers. The table also shows the number of model plant sizes used to calculate costs for the four fertilizer types. The emissions are reduced dramatically below levels that would have been achieved for purely economic recovery purposes. The control costs are shown for investment and cash requirements, as well as for annualized expenditures over the next decade.

Table 3-11-1.
Phosphate Fertilizer Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (1,000 MT/Yr)	37.23	45.17	55.83

Annual Growth Rate Over the Period 1976-85 = 4.66%

PROCESS CHARACTERISTICS	Model Plant Size (MT/Yr)	Pollutants Controlled	Control Technology
Type of Phosphate:			
NSP	62.7;99.0;132.0;165.0; 198.0;231.5	Particulates	Wet Scrubber
NPK	45	Particulates	Wet Scrubber
TSP	70;120;297.5;460;670; 930	Particulates	Wet Scrubber
DAP	54;155;248;378;513; 700;900	Particulates	Wet Scrubber

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	1,104.67	1,428.56	1,773.89		
Legislated Controls:					
Particulates	630.79	2.03	3.49		
CONTROL COSTS (Million 1975 $)					
Investment	23.51	12.23	6.67	175.14	97.40
Total Annual	25.56	51.86	65.38	570.50	512.00
Capital	10.22	19.12	23.04	212.04	188.31
O&M	15.34	32.74	42.34	358.47	323.69

NON-FERTILIZER PHOSPHORUS INDUSTRY

Production Characteristics and Capacities. In 1973, there were 21 plants engaged in the production of elemental phosphorus, defluorinated phosphates (DFP), and calcium phosphates (Dical). The combined capacity of these plants is approximately 4,808 metric tons per day or 1.6 million metric tons per year (P_2O_5 equivalent) in 1973. Ten plants produce elemental phosphorus and account for over 60 percent of the total capacity involved in the production of non-fertilizer phosphates. A summary of model plant size distributions and capacities for the three products is provided in Table 3-12-1.

Table 3-12-1.
Non-Fertilizer Phosphates Industry
Plant Capacity Distribution

	Plant Capacity (P205, MT/day)	No. Plants	Total Capacity (P205, MT/day)	Percent Group	Percent Industry
Phosphate reduction	54	3	162	5	3
	217	4	867	29	18
	649	3	1,948	66	41
		10	2,977	100	62
Defluorinated phosphate	31	1	31	5	nil
	93	1	93	15	2
	125	1	125	20	3
	386	1	386	60	8
		4	635	100	14
Calcium phosphate	54	4	216	18	5
	200	2	400	33	8
	580	1	580	48	12
		7	1,196	100	25
Totals		21	4,808		100

The production of industrial phosphorus and phosphate containing animal feeds begins with thermal and/or chemical processing of phosphate rock. Phosphates that are suitable as additives to feeds may result from the direct defluorination of phosphate rock, defluorination of phosphoric acid from wet process acid, or defluorination of furnace acid, e.g., acid made from elemental phosphorus produced by thermal reduction of phosphate rock. The production of feed-grade phosphates by conversion of elemental phosphorus is expected to decline because of the energy requirements of the thermal reduction of phosphate rock. Decreased production by this process will be compensated for by increased production from wet process acids, so the overall production of feed-grade phosphates will increase at an annual rate of approximately 4 percent. Current production is estimated to be about 90 percent of capacity.

Emission Sources and Pollutants. Atmospheric emissions from the manufacture of defluorinated phosphates are primarily fluorides and particulates. Currently, only Florida has established controls for fluoride emissions; it is anticipated that Federal and state regulations for control of fluoride emissions will be promulgated shortly, and so control costs for this pollutant are included in the analysis for this industry.

Gaseous fluorides are released during the thermal and/or chemical reduction of phosphate rock with the major point of emissions in feed preparation. Emission factors may be as high as 33 kilograms fluorine per metric ton of phosphorus processed.

A summary of estimated fluoride emissions from the production of defluorinated phosphates is presented below; control efficiencies of 95 percent are assumed.

	Present Controls (metric tons/yr)	Further Controls (metric tons/yr)
1975		
Phosphate reduction	430	25
Defluorinated phosphate	2,560	158
Calcium phosphate	40	2
1985		
Phosphate reduction	260	15
Defluorinated phosphate	3,910	242
Calcium phosphate	50	3

Control Technology and Costs. Control of fluorides can be accomplished by the use of wet scrubbers. These devices, which could include liquid ejector venturi scrubbers, liquid impingement control systems, and spray towers, also serve to control particulate emissions to levels of 95 percent or more.

For DFP and Dical plants, control costs are comparable for similar sized plants but almost four times as high as for phosphate reduction plants of similar size. The lower control costs associated with animal feed production from furnace acid is due to the relatively lower percentage of fluorides contained in the phosphoric acid obtained from thermal reduction of rock. Annualized control costs and industry operating statistics are detailed in Table 3-12-2.

Table 3-12-2.
Non-Fertilizer Phosphorus Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985		
Capacity (MT/Day)	5,980.0	6,529.0	8,023.0		
Annual Growth Rate Over the Period 1976-85 = 3.50%					
PROCESS CHARACTERISTICS	Model Plant Sizes	Pollutants Controlled		Control Technology	
Deflourinated Phosphate	See Table 3-12-1.	Particulates		Wet Scrubber	
Phosphate Reduction		Particulates		Wet Scrubber	
Calcium Phosphate		Particulates		Wet Scrubber	
EMISSIONS (MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	34.54	47.84	58.69		
Legislated Controls:					
Particulates	28.07	32.45	39.91		
CONTROL COSTS (Million $)					
Investment	1.68	0.58	0.28	10.60	5.66
Total Annual	1.10	2.07	2.39	22.29	19.88
Capital	0.80	1.52	1.73	16.22	14.47
O&M	0.30	0.55	0.66	6.07	5.42

SULFURIC ACID INDUSTRY

Production Characteristics and Capacities. About half of the sulfuric acid produced in the United States is used in the manufacture of phosphate fertilizers; the rest is used in myriad industrial applications ranging from steel pickling to detergent manufacturing.

Sulfuric acid is manufactured by chemical companies and by companies primarily engaged in smelting nonferrous metals; both sources compete for the same buyers. Nevertheless, the manufacturing of sulfuric acid by the smelter industry is primarily a byproduct resulting from the control efforts to reduce sulfur dioxide emissions to the atmosphere, and secondarily, as an attempt to generate additional revenue. For the purposes of this report, smelter acid is considered to be part of the smelter industry rather than the sulfuric acid industry.

The major products of the sulfuric acid industry are concentrated sulfuric acid (93 to 99 percent) and oleum. A few sulfuric acid plants associated with the fertilizer industry produce less-concentrated grades of acid. Essentially, all sulfuric acid in the United States is currently produced by the contact process, less than 0.4 percent is being produced by the older chamber process.

In sulfur-burning plants, sulfuric acid is produced by burning elemental sulfur with dry air in a furnace to produce sulfur dioxide. The latter is catalytically converted to sulfur trioxide. The hot converter effluent is cooled and introduced to an absorption tower where the sulfur trioxide is absorbed in a sulfuric acid solution to form more sulfuric acid by its reaction with water.

Some plants (including spent-acid plants and smelter-gas plants) operate on the same principle as sulfur-burning plants, except that the sulfur dioxide is obtained from the combustion of spent acid and hydrogen sulfide or from smelter off-gas. In these plants, the sulfur-bearing gas is dried with sulfuric acid and cleaned (subjected to particulate and mist removal process) before introduction to the acid plant.

Of the known 183 sulfuric acid plants operating in 1973, 167 were contact process plants and 16 were chamber process plants. Of the 25.5 million metric tons of new sulfuric acid produced, 25.3 million metric tons were made in contact process plants. This volume production included sulfuric acid produced by the sulfuric acid industry (as defined in this report) and by the smelter industry. In 1974, 58 companies operated sulfur-burning or wet-process contact acid plants in 134 locations, and 16 companies operated smelter acid plants in 23 locations. In addition, five companies operated small chamber-acid plants in five locations.

Emissions Sources and Pollutants. Emissions from sulfuric acid plants consist of sulfur dioxide gases and sulfuric acid mist. These pollutants evolve from incomplete conversion of sulfur dioxide to sulfur trioxide in the converter, and from the formation of a stable mist consisting of minute particles of sulfuric acid that resist absorption in the acid absorber.

Controlled Technolocy and Costs. The controlled emission factors for existing facilities for FY 1976 are as specified by the SIP's; new source values were assumed to apply to both existing and new facilities in FY 1980.

In sulfuric acid plants using the two-stage or dual absorption control process, the gas from the first acid absorber is initially heated (sometimes removing the mist) and then sent through a single-stage converter where the sulfur dioxide is converted to sulfur trioxide. The gas from the converter is then sent to an absorber and a demister before release to the atmosphere.

Dual adsorption has reliably met EPA standards of performance for new and modified sources in applications of two types of sulfuric acid plants (sulfur-burning and wet gas) of all sizes. In addition to controlling sulfur dioxide emissions, the dual absorption method offers the added advantage of not requiring new operational skills on the part of acid plant operators. This control technology has been used in computing the sulfur dioxide control costs for all new and existing sulfuric acid plants.

Table 3-13-1 shows that capacity is increasing at a substantial rate for this industry, with associated costs reflecting this trend. This may cause the costs to be overstated due to the rapid increase in sulfuric acid recovered in the control of sulfur oxides from smelters and utility plants. The control costs are also shown for total annualized expenditures, investment and cash requirements.

Table 3-13-1.
Sulfuric Acid Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (1,000 MT/Day)	94.2	127.1	152.8

Annual Growth Rate Over the Period 1976-85 = 5.40%

PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Day)	Pollutants Controlled	Control Technology
Sulfur Burning	297;665;1,814	Sulfur Oxide & Acid Mist	Dual Absorption
Wet Gas		Sulfur Oxide & Acid Mist	Dual Absorption

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Sulfur Oxides	711.36	982.04	1,180.74		
Other Gases & Mists	22.92	31.65	38.05		
Legislated Controls:					
Sulfur Oxides	337.58	99.03	119.44		
Other Gases & Mists	11.35	4.27	5.14		
CONTROL COSTS (Million 1975 $)					
Investment	148.94	12.17	5.76	721.90	247.89
Total Annual	109.93	175.51	181.50	1,919.29	1,673.29
Capital	72.98	107.62	111.18	1,200.52	1,036.32
O&M	36.95	67.88	70.32	718.77	636.97

PETROCHEMICALS INDUSTRY

Production Characteristics and Capacities. In estimating air emission control costs associated with the petrochemical industry, the production of the following major large volume petrochemicals was considered:

- Formaldehyde
- Acrylonitrile
- Ethylene dichloride
- Ethylene oxide
- Phthalic anhydride.

A major air pollution problem in the petrochemical industry is the emission of hydrocarbons and carbon monoxide via off-gases produced in oxidation processes. The petrochemicals involved in this problem include not only oxygen-containing compounds, such as oxides, aldehydes, and anhydrides, but also compounds in which oxygen serves an intermediate role in the synthesis, such as acrylonitrile and ethylene dichloride. In a typical process of this type, the raw material, air (sometimes oxygen), and sometimes a third reactant are fed into a vapor-phase catalytic oxidation reactor. The reactor effluent gases go to an absorber in which the desired product is scrubbed out. The off-gas from this absorber, which is vented to the atmosphere, contains mostly nitrogen and carbon dioxide, but smaller amounts of carbon monoxide and unconverted hydrocarbons are also present.

Formaldehyde. Formaldehyde is synthesized by oxidation of methanol with air and sold as an aqueous solution (37 percent by weight). Two different processes are used, one based on a metal oxide catalyst and one based on a silver catalyst; about 77 percent of the domestic formaldehyde production uses the silver process and the other 23 percent uses the metal oxide process.

Production in 1974, as estimated from data for the first 8 months of the year, was about 2.8 billion kilograms of 37 percent formaldehyde. Growth is due primarily to increased demand for urea-formaldehyde and phenolformaldehyde resins, which consume about half of all the formaldehyde produced.

Acrylonitrile. Ammoxidation of propylene, the most widely practiced method for producing acrylonitrile, consists of the catalytic oxidation of ammonia with air. Typically, the gaseous products from the oxidation chamber are passed to an absorber where the acrylonitrile is collected. The off-gas from the absorber is normally vented to the atmosphere, a process which is largely uncontrolled at present.

Production in 1974, as estimated from data for the first eight months of the year, was about 681 million kilograms. Growth is due primarily to increased demand for acrylic fibers, which consume about half of all the acrylonitrile produced, and for plastics, which consume another 15 percent of total production.

Ethylene Dichloride (EDC). Ethylene dichloride can be produced by two alternative processes, direct chlorination or oxychlorination. While half of the U.S. production of EDC is by direct chlorination, the process results in only 10 percent of the volume of atmospheric emissions that result from the oxychlorination process and, hence, only oxychlorination is considered here.

Production in 1974, as estimated from data for the first eight months of the year, was about 3.5 billion kilograms. The use of the oxychlorination process should continue to account for about 48 percent of the total production, or about 2.8 billion kilograms in 1985.

Ethylene Oxide. In recent years, the dominant process for manufacturing ethylene oxide has become the direct oxidation of ethylene. There are four processes used for ethylene oxide manufacture by direct oxidation and all use a silver catalyst. Only two of the plants oxidize with dioxide, the others use air. The plants which oxidize with dioxide are similar except that usually only a primary reactor and absorber are used. Compared to the plants which use air, the plants which use dioxide produce much less absorber gas but much more carbon dioxide rich purge gas.

Phthalic Anhydride. Phthalic anhydride is produced by the oxidation of either o-xylene or naphthalene; about 55 percent of the phthalic anhydride is produced from o-xylene. This process is expected to gain an increasing share of industrial production because oxylene is less expensive than naphthalene.

A number of processes are available for producing phthalic anhydride. Most of the naphthalene-based processes use fluidized-bed reactors, whereas all xylene-based processes use tubular fixed-bed reactors. Except for the reactors and the catalyst handling facilities required for the fluidized-bed units, the processes based on the two raw materials are quite similar. In both cases, the reactor effluent gases are used to generate steam in a waste heat boiler and then go to a seperation system in which the phthalic anhydride is condensed out as solid crystals. The condenser effluent gases are ultimately vented to the atmosphere, although in most plants they are first water-scrubbed or incinerated.

Emission Sources and Pollutants. Atmospheric emissions arising from petrochemical production result from the venting of off-gases from the absorber. The chief air pollutants are hydrocarbons and carbon monoxide. Corresponding emission factors for these pollutants as a function of production volume are given in Table 3-14-1.

Table 3-14-1.
Petrochemicals Industry
Calculated Emission Factors

(No Controls)

Petrochemical	Waste Gas Streams	Kilograms Emitted Per 10^3 Kilograms of Product		
		CO	Hydrocarbons	SO_x (as SO_2)
Formaldehyde (37%)	Absorber vent	3.33	5.28	-
Acrylonitrile	Absorber vent	74.19	83.52	-
Ethlene dichloride	Absorber vent	3.31	12.94	-
Ethylene oxide	Absorber vent + CO_2 purge	0.	50.15	-
Pthalic anhydride	Absorber vent	73.76	19.50	2.29

Control Technology and Costs. The control technology judged to be most feasible for control of hydrocarbon and carbon monoxide emissions from the manufacture of petrochemicals is thermal incineration (often referred to as afterburners). Thermal incinerators were considered in place of catalytic incinerators because of the latter's higher initial investment costs and requirement for catalyst replacement costs. The investment for thermal incinerators was based on a compilation of costs by the Midwest Research Institute (MRI), which considered the purchased cost of a thermal incinerator plus the heat exchanger in which the effluent gases heat up the influent gases. These costs were inflated to mid-1973 using the Chemical Engineering Plant Cost Index and were found to compare closely with investment data provided in a recent report by Houdry on acrylonitrile. Annual costs were calculated from utility (fuel and power) requirements, annual maintenance, and operating labor.

The distribution of plant size categories, number of plants, capacity and percent of industry capacity represented by model size, and the unit investment and annual operating and maintenance costs are given in Table 3-14-3 for each petrochemical production process covered. Annualized Industry costs for air pollution abatement in the period 1976-85 are also provided in Table 3-14-2.

Table 3-14-2.
Petrochemicals Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (Million Kg/Yr)	4,111,700	5,361,100	6,598,900

Annual Growth Rate Over the Period 1976-85 = 5.83%

PROCESS CHARACTERISTICS	Model Plant Sizes (1/2 MT/Yr)	Pollutants Controlled	Control Technology
Formaldehyde-Silver Process	34.2;89.2;149.6; 492.2	Hydrocarbon; Carbon Monoxide	Afterburners
Formaldehyde-Metal Oxide Process	43.5;90.0;123.8	Hydrocarbon; Carbon Monoxide	Afterburners
Phthalic Anhydride	38.6;87.9;128.8	Hydrocarbon; Carbon Monoxide	Afterburners
Acrylonitrile	178;270	Hydrocarbon; Carbon Monoxide	Afterburners
Ethylene Oxide - O2	210.3	Hydrocarbon	Afterburners
Ethylene Oxide - Air	71.2;303.8;733.3	Hydrocarbon	Afterburners
Ethylene Dichloride	177.5;425;695	Hydrocarbon; Carbon Monoxide	Afterburners

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Hydrocarbons	410.83	621.17	713.65		
Carbon Monoxide	171.28	273.58	316.90		
Legislated Controls:					
Hydrocarbons	182.25	31.24	37.27		
Carbon Monoxide	79.11	14.83	17.14		
CONTROL COSTS (Million 1975 $)					
Investment	3.85	2.00	1.04	48.51	25.90
Total Annual	25.58	49.85	57.20	528.17	471.73
Capital	2.67	5.29	5.89	55.33	48.93
O&M	22.90	44.56	51.31	472.84	422.81

PETROLEUM INDUSTRY

Production Characteristics and Capacities. The petroleum industry can be divided into the following four operating areas:

Exploration and production, which includes the search for new oil supplies, the drilling of oil fields, removal of oil from the ground, and pretreatment at the well site.

Refining, which includes the operations necessary to convert the crude oil into salable products such as gasoline, jet fuel, kerosene, distillate and residual fuel oils, lubricants, asphalt, specialty products, and chemical raw materials such as ethylene and benzene.

Transportation, which involves the movement of crude oil to the refinery and refined products to market areas.

Marketing, which involves the distrubution and sale of the finished products.

Integration and diversification prevail within the industry. Most of the firms involved in refining are also involved in production and/or marketing. All the large and medium sized firms are involved in the manufacture of petrochemicals. Some firms are involved in the production aspects of energy sources other than crude oil, i.e., coal or Canadian tar sands.

As of January 1, 1974, the 247 refineries in the United States had a total crude oil capacity of 14.2 million barrels per day. A distribution of these refineries by size and percent of total capacity is as follows:

Capacity Range (1,000 bbl Cal day)	No. Refineries	Total Capacity (1,000 bbl Cal day)	Total Industry Capacity(%)	Average Capacity (1,000 bbl Cal day)
Up to 5	46	144	1.01	3
5 to 10	30	236	1.66	8
10 to 15	21	274	1.92	13
15 to 25	21	437	3.07	21
25 to 50	45	1,645	11.57	37
50 to 75	23	1,444	10.15	63
75 to 100	20	1,831	12.88	92
100 to 200	26	3,657	25.72	141
Over 200	15	4,550	32.02	303
Totals	247	14,216	100.00	

During the period from 1970 to 1974, total crude processing capacity increased by 2.1 million barrels per day, despite a drop in the number of refineries from 262 to 247, indicating a gradual trend toward larger plants. Although there are about 130 firms which operate refineries, over 80 percent of the total capacity is controlled by 17 major firms; each firm controls crude processing capacity in excess of 200,000 barrels per day. A breakdown of capacity and number of plants operated by these firms is as follows:

Company	No. Refineries	Crude Capacity (1000 bbl/cal day)	Crude Capacity (%)
Exxon	5	1,252	8.8
Shell	8	1,109	7.8
Texaco	12	1,083	7.6
Amoco	10	1,065	7.5
Standard (CA)	12	984	6.9
Mobil	8	932	6.6
Gulf	8	861	6.1
ARCO	6	790	5.6
Union Oil	4	487	3.4
Sun Oil	5	484	3.4
Phillips	6	404	2.8
Sohio/BP	4	384	2.7
Ashland	7	358	2.5
Continental	7	349	2.5
Marathon	3	314	2.2
Cities	1	268	1.9
Amer. Petrofina	4	200	1.4
Subtotal	110	11,324	79.7
Remaining Firms	137	2,892	20.3
	247	14,216	100.0

The intensity of the energy shortage resulted in the largest absolute capacity increase since 1967, and the largest percentage increase in at least a decade. The increase was 6.2 percent, compared with 2.3 - 4.3 percent for the preceding 3 years.

Very few new refineries have been built in the last 5 years; the growth has occurred primarily through the expansion of existing facilities. This is in part due to difficulty in securing approval for new sites. A survey of refinery construction plans in August of 1973 showed "definite projects" for 1974-77 totaling 1.13 million barrels per day (all expansions) and projects "under study" totaling about 0.9 million barrels per day (mostly new refineries).

Turning now to the aspects of the petroleum industry which are of particular importance in air pollution abatement, the capacity of fluid bed catalytic cracking is expected to grow at the same rate as total refinery capacity, i.e., 4.2 percent per year.

It is estimated that the 247 domestic refineries produce about 70 million cubic meters per day of refinery gases. The present Claus plant capacity for recovering sulfur from these gases is about 8,300 metric tons per day.

Emission Sources and Pollutants. The three major sources of air pollution in the petroleum industry covered in this report are regeneration of catalysts used in catalytic cracking, burning of fuel gases from various refinery process operations in order to recover the fuel values, and handling and storage of volatile petroleum products and crude oils. A consolidated view of the type and extent of the emissions from refining and related operations, is presented below.

Catalytic Cracking. Catalyst regeneration during the operation of catalytic cracking units has been identified as a major source of carbon monoxide, unburned hydrocarbons, and, in the case of the fluid bed units which dominate this process, particulate emissions. The coke deposited on the catalyst during the cracking operation must be continually removed to permit the catalyst to maintain high activity. In a fluid bed catalytic cracker, the catalyst bed is continuously circulated between the reactor, where the coke is deposited on the catalyst, and the regenerator, where it is burned off with air. The amount of coke deposited on the catalyst per unit of feedstock is a function of the feedstock and operating conditions.

Fuel Gas Burning. Currently, amine scrubbing units are widely used to remove hydrogen sulfide from the fuel gas generated within refineries. The hydrogen sulfide is thermally stripped from the scrubbing liquor and then is either sent to a sulfur recovery plant (usually a Claus plant) or is burned to sulfur dioxide, which is emitted to the atmosphere through a flare. In 1973, about 70 percent of the sulfur which went into fuel gas was recovered as elemental sulfur, the other 30 percent was emitted as sulfur dioxide.

Petroleum Storage. The most significant contribution to total hydrocarbon losses in the petroleum industry is associated with the necessary use of vast storage facilities. The National Petroleum Council has shown that the entire industry maintains a total storage capacity of at least two barrels for each barrel of actual inventory. This is the minimum amount necessary to insure continuous refinery operations and to provide for seasonal variations in product demands. The magnitude of hydrocarbon emissions from storage tanks depends on many factors including the physical properties of the material being stored, climatic and meteorological conditions, and the size, color, and condition of the tank.

Control Technology and Costs. Control technology and costs for the three major emission sources in the petroleum industry are outlined in the following paragraphs.

Catalytic Cracking. The removal of particulate matter (catalyst fines) from the regenerator gas can be accomplished with high-efficiency electrostatic precipitators. Although some reduction in carbon monoxide and unburned hydrocarbons can be achieved by increasing the regeneration temperature, essentially complete removal of these species will require carbon monoxide boilers. The additional combustion which occurs in the carbon monoxide boiler generates substantial quantities of heat, which the boiler recovers as steam; the value of this steam helps offset the cost of the equipment. Equipment for controlling emission of particulate matter, carbon monoxide, and hydrocarbons is commercially available and is already in use in some catalytic cracking units.

In 1971, about 29 percent of the fluid catalytic cracking capacity was equipped with electrostatic precipitators and about 69 percent was equipped with carbon monoxide boilers. These boilers are often economically justified by the steam which they generate, especially for large catalytic cracking units. Increasing energy costs are making carbon monoxide boilers more attractive for this reason. In some existing refineries, the additional steam generated by the addition of a carbon monoxide boiler cannot be used, but new refineries can be designed to take advantage of this means of reducing their total energy requirement.

The catalyst fines collected by the electrostatic precipitator must be disposed of as solid waste. Costs for this phase of disposal were calculated using the average particulate emission factor for fluid cat crackers (110 kg/1000 bbl fresh feed), a precipitator efficiency of 93 percent, and an operating factor of 0.913 (8,000 hr/yr).

Annualized control costs and control data are detailed in Table 3-15-1.

Fuel Gas Burning. The control technology involves installing additional amine scrubbing facilities where required, installing Claus plants on the 30 percent of capacity now without them, and installing tail-gas treatment facilities on all the Claus plants. The tail-gas treatment facilities increase the overall sulfur recovery from about 95 to 99.8 percent.

The amine solution used in the scrubbing operation cannot be regenerated and reused indefinitely. Complex sulfur salts are formed which must be purged from the system, and fresh solution must be added to replace the amine thus lost. Two methods are used commercially: one involves continuously withdrawing a purge stream, and the other involves using the solution for a period of time and then completely replacing it. For analyzing salt disposal costs, an equivalent daily purge rate relationship of 1.74 pounds per day amine purge per long ton per day sulfur recovery was used.

The credit for the sulfur recovered in these processes is an important economic consideration and is also difficult to define. In the coming years, the reduction of allowable sulfur emissions from refineries, power plants, etc., plus the increasing sulfur content of the crude oil processed will combine to cause a very large increase in the production of sulfur. This will probably depress the price of sulfur, but the extent of depression is open to considerable speculation. The price level used in this study was: $15 per metric ton.

Annualized control costs and control data are detailed in Table 3-15-1.

Hydrocarbon Storage. The EPA new source pollution regulations require that petroleum products having vapor pressures of 78 to 570 milliliters of mercury be stored in floating roof tanks or their equivalent. There is also a requirement for products with vapor pressure greater than 570 milliliters of mercury, but this will cause no additional expense since the control methods are presently used for these products. Thus, this report is concerned only with the storage of crude oil, jet fuel, and gasoline.

The typical industry practice (1968) involved a distribution of 75 percent floating-roof and 25 percent fixed-roof tanks; this distribution is felt to be applicable for crude oil and jet fuel. For gasoline, the economics of evaporation control have led to a distribution more like 90 percent floating-roof and 10 percent fixed-roof. Thus, the cost of meeting the new regulations is the difference between the cost of using 100 percent floating-roof tanks for these products and the cost of using the above distributions.

The tank costs were based on quotations obtained in October of 1974 from representative vendors. These quotations were for a typical midwestern location. The following items were added to the basic tank cost:

Item	Tank Cost (%)
Excavation and dike	25
Foundation	6
Electrical grounding	3
Piping, etc.	10
Painting	3
Total	47

These percentages were taken from a report by the MSA Research Corporation; no land cost was included. Quotations were obtained for both fixed-roof and floating-roof tanks. The difference between these two is then the differential cost applicable to new tanks. Since the desired time basis for this study is mid-1973, these costs were adjusted back to that time using the Nelson refinery cost index. Quotations were also obtained for converting existing fixed-roof tanks to floating-roof by retrofitting an internal floating cover. This is the conversion method which will evidently be used, since it costs only about half as much as removing the fixed roof and replacing it with a floating roof.

The most recent analysis of costs for this sector was provided to the Environmental Protection Agency by Sobotka & Co., Inc. (S&C)[1]. This analysis was conducted in somewhat greater depth than, and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure, and is considered to be more precise. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The S&C estimates are as follows (in million 1975 dollars):

Incremental Investment	(1975-1983)	1,280
	(1974-1977)	740

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. SEAS forecasts an investment costs of $783 million for 1975-1983. This assumes that 46 percent of the required pollution control equipment was installed by 1975. The total cost of meeting the standard over 1972-1979 is $1,223 million. Thus, the assumed time pattern of capital expenditures of the two studies greatly affects the cost comparisons for a particular span of years.

The S&C study developed its cost data for two main categories--large and small plants. The data for both groups was based upon a representative sample, and then extrapolated for the whole group. SEAS used the model plant concept, with several different model plants for three main categories: catalytic cracking, fuel gas burning, and petroleum storage. These assumptions are listed in Table 3-15-1 and process characteristics.

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[1] "Economic Impact of EPA's Regulations on the Petroleum Refining Industry", Sobotka & Co., Inc., April, 1976.

Table 3-15-1.
Petroleum Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity			
Storage - Million Bbl/Day	783,020	931.730	1,140,400
Catalytic Cracking 10^3 Bbl/Day)	2,778,313	3,325,400	3,975,900
Refining - MT/Yr Revised	4,282	5,126	6,128
Annual Growth Rate Over the Period 1976-85	Storage 4.18% Catalytic Cracking 3.99% Refining 3.99%		

PROCESS CHARACTERISTICS	Model Plant Sizes (Million Bbl/Day)	Pollutants Controlled	Control Technology
Gasoline Storage	56	Hydrocarbons	Floating Roof
Crude Oil Storage	80	Hydrocarbons	Floating Roof
Jet Fuel Storage	56	Hydrocarbons	Floating Roof
Catalytic Cracking	1.6, 9.6, 30	Particulates, Carbon Monoxide Hydrocarbons	ESP
Refining (1,000 Bbl/Day)	5, 10, 31, 67, 93, 211	Sulfur Oxides Hydrocarbons Carbon Monoxide	Tail Gas Treatment

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	98.32	124.78	147.38		
Sulfur Oxides	2,542.34	3,226.72	3,811.17		
Hydrocarbons	933.45	1,178.14	1,424.74		
Carbon Monoxide	2,702.98	3,430.61	4,051.98		

Table 3-15-1. (Continued)
Petroleum Industry Data Summary

Legislated Controls:

Particulates	42.64	18.12	2.15
Sulfur Oxides	1,328.85	472.02	560.93
Hydrocarbons	576.06	353.69	421.85
Carbon Monoxide	1,217.28	142.94	52.27

Table 3-15-1. (Continued)
Petroleum Industry Data Summary

CONTROL COSTS (Million 1975 $)	1975	1980	1985	1971-85	1976-85
Catalytic Cracking:					
Investment	55.66	20.38	13.39	581.90	275.42
Total Annual	49.42	83.37	94.32	934.70	815.66
Capital	40.30	68.24	76.54	763.41	664.77
O&M	9.12	15.13	17.77	171.29	150.89
Fuel Gas Burning:					
Investment	49.36	18.41	9.86	515.03	229.50
Total Annual	90.35	143.46	158.10	1,619.70	1,407.23
Capital	37.54	61.01	67.71	686.16	593.32
O&M	52.81	82.45	90.38	933.53	813.91
Storage:					
Investment	46.60	19.00	11.88	361.09	186.86
Total Annual	18.48	31.60	38.31	357.28	314.93
Capital	18.48	31.60	38.31	357.28	314.93
O&M	0	0	0	0	0

FERROALLOY INDUSTRY

Production Characteristics and Capacities. In 1972, there were 26 companies operating an estimated 44 ferroalloy plants. The industry is composed of steel companies, chemical and mineral companies having access to particular alloying elements, and specialist producers of ferroalloys. Five companies use the metallothermic process to make specialty ferroalloys containing molybdenum, tungsten, vanadium, columbium or titanium. Six companies are involved in making ferrophosphorus. The remaining companies use the submerged-arc electric furnace to produce about one-half of the ferromanganese and virtually all of the silicon- and chromium-containing ferroalloys used in steelmaking.

Alloying elements required for making different steels are often added in the form of ferroalloys which contain iron and at least one other element. The ferroalloys are named according to the major alloying element: ferromanganese contains manganese as the additive; ferrochromesilicon contains both chromium and silicon. Some additives in which the iron content is very small (such as silicomanganese and silicon-chrome-manganese) are also considered as ferroalloys.

Ferroalloys are made by three methods with submerged-arc electric furnaces producing most of the output. Three types of furnaces are adapted to the three production methods: open furnaces, semicovered furnaces, and sealed furnaces. Metalothermic reduction furnace production has been included with electric furnace production in the absence of sufficient information on number, location, emissions, and air-pollution-control methods. Two domestic producers use blast furnaces for making ferromanganese and occasionally ferrosilicon.

Emission Sources and Pollutants. Particulate emissions are generated during the handling of the ores, fluxes, and reductants used in the production of ferroalloys. Particulate and gaseous emissions are continuously evolved during smelting operations. Fuming occurs when the ferroalloy is poured, the amount varying with the particular ferroalloy. Submerged-arc electric furnaces of the open or open-hood type are required because of the formation of crusts with certain ferroalloys; these crusts must be broken mechanically. With semicovered or low-hood type submerged-arc furnaces, the charge is fed to the furnace through openings around the electrodes. In open-hood furnaces, the collection hood is raised sufficiently to provide room for charging between the hood and the charging floor; in semicovered furnaces, the hood is lower and water-cooled.

Open and semicovered furnaces produce greater emissions than sealed furnaces, which are used to prevent the escape of emissions and to minimize the influx of air.

Metallic silicon and aluminum are very strong deoxidizers which are used under high-temperature conditions to reduce the mineral oxides of molybdenum, titanium, zirconium, and similar metals in metalothermic reduction furnaces.

In blast furnace smelting operations, particulates and gaseous emissions are carried out of the furnace in the same off-gas stream.

Control Technology and Costs. Baghouses, electrostatic precipitators (ESP), and high-energy scrubbers are all used to control emissions from submerged-arc electric furnaces. Fumes evolving from the casting of ferromanganese in blast furnace operations must also be controlled by baghouses.

A total of 155 ferroalloy furnaces were used in developing the model furnaces used to produce cost estimates; however, only 56 furnaces could be identified as to specific ferroalloy produced and the furnace electric power rating. The distribution for these 56 furnaces was assumed to represent the size distribution for all the existing furnaces. Emissions from ferroalloy furnaces are related to the furnace electric power input.

A relationship between furnace power input and production was used to estimate furnace capacity. Capacities of open-hood and low-hood electric furnaces were related to the capacities of baghouse, scrubber, and electrostatic precipitator control devices required to satisfy the requirements.

To estimate these air pollution control expenditures, the existing ferroalloy industry was divided into three segments. These segments are shown in Table 3-16-1 under the Process Characteristics heading. Annualized production and cost control data is presented in Table 3-16-1.

Table 3-16-1.
Ferroalloy Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985		
Capacity (1,000 MT/Yr-KVA)	3,168.0	3,992.0	4,368.0		
Annual Growth Rate Over the Period 1976-85 = 4.07%					
PROCESS CHARACTERISTICS	Model Plant Sizes (1,000 MT/Yr)	Pollutants Controlled		Control Technology	
Open and Low Hoods	14.5;37;41	Particulates		Baghouse	
Open and Low Hoods	33	Particulates		Scrubber	
Low Hoods	32	Particulates		ESP	
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	162.01	226.45	255.97		
Legislated Controls:					
Particulates	74.28	8.24	8.97		
CONTROL COSTS (Million 1975 $)					
Investment	71.05	1.23	0.13	339.73	117.14
Total Annual	44.96	68.82	68.27	752.71	654.27
Capital	36.24	54.42	55.30	598.49	519.02
O&M	8.73	14.40	12.97	154.22	135.25

IRON AND STEEL INDUSTRIES

Production Characteristics and Capacities. The iron and steel industry production operation includes the following major sequential processes: recycling (sintering), coke production, and steelmaking. There are three types of steelmaking: open-hearth (OH), basic-oxygen furnace (BOF), and electric-arc furnace (EAF).

Sintering is the process by which iron-ore fines and reclaimed iron dusts, sludges, and scale generated in various iron and steelmaking processes are agglomerated and prepared for charging in blast furnaces. Coking is the process used to convert suitable grades of coal to metallurgical coke for charging in the blast furnace. Blast-furnace operation is a smelting process by which iron ore is reduced to pig iron; open-hearth, basic oxygen, and electric-arc furnaces are used to make steel.

Sintering Plants. There are 15 companies operating 43 recycling or sintering plants ranging in size from about 180,000 metric tons per year to 4.3 million metric tons per year. Sintering plants have been grouped into 14 categories based on size and applicable pollution control regulations. Sintering consists of agglomerating ore fines and reclaimed iron-containing dusts, sludge, and scale generated in various iron and steelmaking processes. Sinter is made by mixing these fines with limestone and coke (or anthracite coal), charging the mixture onto a continuous traveling grate, and igniting the mixture. Air is blown through the mixture to support combustion. The sintering is completed by the time the end of the grate is reached. The sinter clinker is cooled, crushed, and screened to size for charging to the blast furnace.

Coke Plants. The vast bulk of the coke production is owned by iron and steel companies (or affiliates). About 10 percent of the coke is produced in merchant plants for sale in the open market to foundries, other industrial users, or for internal consumption for other than steel-producing purposes.

Coking coals are received at a coal preparation facility where they are finely pulverized and mixed in the required proportions to meet specifications for the blast furnace or for other end uses. The prepared coal mixture is delivered to storage bunkers above the coke oven batteries. Measured quantities of the mixture are withdrawn from the bunkers and carried to individual ovens for charging. The coal is heated in the absence of air for a period of 14 to 18 hours at temperatures of from 900° to 1100°C to convert the coal to coke having the desired properties. During the coking cycle, volatile constituents and noncondensible gases are distilled and transferred via collecting mains to the byproducts plant for the recovery of the gas and various chemicals. When the coking cycle is completed, the doors on the ends of the oven are removed and a ram pushes the incandescent coke from the oven into a quench car. The hot coke is transported to a quench tower where it is cooled under a direct water spray. The coke is then crushed and screened for use in the blast furnace or for other purposes. The fines from the crushing operation are used as a fuel in sintering operations, or are sold commercially.

Open-Hearth Steelmaking. This method is the oldest of the three steelmaking processes presently being used to produce raw steel. Open-hearth steel production has declined from a peak of 89 million metric tons in 1964 to about 36 million metric tons in 1973. In 1973, there were an estimated 18 operating open-hearth shops in the integrated iron and steel industry. It is doubtful that any new plants will be constructed. Furnace capacities range from 50 to 300 net metric tons of steel. For this report, the open-hearth plants have been grouped into five model sizes as follows:

Average Size (1,000 metric tons/year)	No. Plants	Capacity (million metric tons/year)	Total Capacity (%)
283.4	2	0.57	2.0
982.6	3	2.95	10.4
1360.5	6	8.16	28.9
1814.0	4	7.26	25.7
3099.0	3	9.30	32.9

The open-hearth furnace is a shallow-hearth furnace that can be alternately fired from either end. The process consists of charging scrap, fluxes, and molten pig iron into the furnace where the required melting and refining operations are performed to produce the desired analysis of steel. Firing of an open hearth can be done with a variety of fuels, depending on availability, cost, and sulfur content in the fuel.

Basic-Oxygen Furnace Steelmaking. BOF was first used to produce steel in the United States in 1955. By 1965, economic replacement of the open-hearth furnace by the BOF had been well established. BOF steelmaking expanded rapidly to about 76 million metric tons in 1973. Recently, a newer process called Q-BOF has been used for commercial production of steel. This new process has been included with the BOF process for the purposes of this report. In 1973, there were 19 companies operating 38 BOF plants, ranging in size from 450,000 metric tons to 4.3 million metric tons of annual capacity. For the purposes of this report, these plants have been grouped into four model sizes as follows:

Average Size (net metric tons/year)	No. Plants	Capacity (million metric tons/year)	Total Capacity (%)
68-127	10	11.2	14.7
136-172	5	8.1	10.7
181-240	20	46.0	60.7
263-295	3	10.5	13.9

In BOF steelmaking, the pear-shaped, open-top vessel is positioned at a 45-degree angle and charged with the required amount of steel scrap, molten pig iron, and other materials. The vessel is vertically positioned and high-purity oxygen is blown into the molten bath through a water-cooled oxygen lance positioned above the bath. Products of the oxygen reaction with the carbon, the silicon, and the manganese in the charge pass off as carbon monoxide and carbon dioxide gases, and manganese and silicon oxides in the slag. When the required content of carbon, silicon, and manganese is obtained in the melt, oxygen blowing is stopped, and ferroalloys are added as needed to attain the desired final chemical composition of the steel. The molten steel is then poured into a ladle for transfer to subsequent operations.

Electric-Arc Furnace Steelmaking. This process has long been the established unit for the production of alloy and stainless steels. More recently, it has been widely used in mini-steel plants to make plain carbon steels for local markets. In 1972, electric-arc furnace production amounted to 1.5 million metric tons of stainless steel. In 1973 there were almost 100 companies operating electric-arc furnace plants ranging in size from 9 thousand metric tons to 1.2 million metric tons annual capacity. The total electric-arc furnace production in 1973 was about 25 million metric tons. For the purposes of this report, electric-arc furnaces have been grouped into six model sizes as follows:

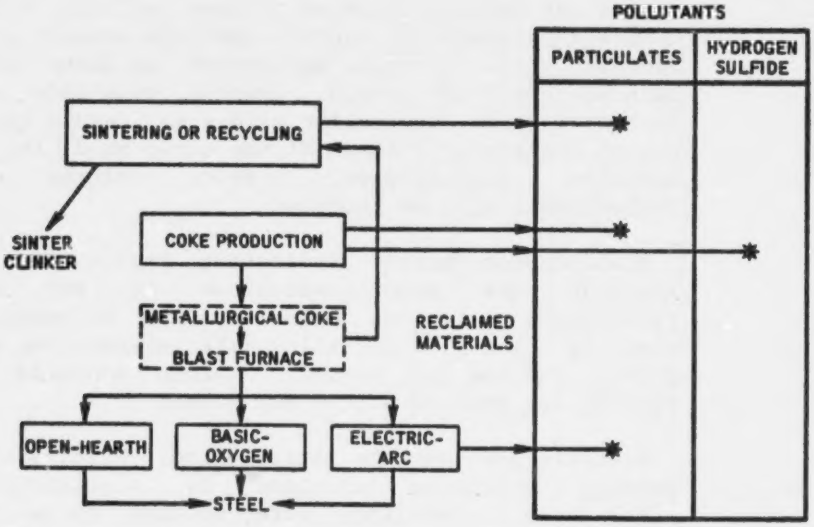
Average Size (1,000 metric tons/year)	No. Plants	Capacity (million metric tons/year)	Total Capacity (%)
45-77	11	1.0	4.0
82-127	26	2.5	10.1
136-204	21	3.4	13.4
218-340	11	3.1	12.3
363-544	21	9.1	36.1
907-1197	6	6.1	24.2

The electric-arc furnace is a short, cylindrical-shaped furnace having a rather shallow hearth. Three carbon electrodes project through the fixed or moveable roof into the furnace. Charge materials consist of prepared scrap, although one or two electric furnace shops make use of molten pig iron as part of the charge. After charging, the melting operation is started by turning on the electric power to the electrodes which are in contact with the scrap. Electrical resistance of the scrap produces heating and eventual melting of the scrap. Additional scrap is added, and refining is accomplished by blowing high-purity oxygen into the molten scrap to remove carbon and silicon. Ferroalloys are added as needed to attain the desired final chemical composition of the steel. Power is shut off and the molten metal is tapped into a ladle.

Emission Sources and Pollutants. The processes employed in producing steel are shown in Figure 3-17-1. Five of these processes are important generators of air emissions, and therefore they must be controlled to meet State Implementation Plans and Federal New Source Performance Standards. Fugitive emissions are not considered in this study. However, in the case of certain steel plants control of fugitive emissions may be necessary in order to meet air quality standards.

Sintering Plants. The emissions associated with sinter plant operations are particulates that (1) become entrained in the combustion air as it is drawn through the sinter mixture into the windbox, (2) are generated during the cooling operation, and (3) are generated during the crushing and screening operations. Sulfur contained in the fuel is not considered to be a major problem, although any sulfur present in the sinter mix or in combustion fuel will be emitted as sulfur oxides.

Figure 3-17-1.
Iron and Steel Production Processes



Coke Plants. Emissions from the production of coke occur as particulates, hydrogen sulfide, sulfur oxides, carbon monoxide, hydrocarbons, and nitrogen oxides. Particulate emissions occur from the following sources: coal receiving and stockpiling, coal grinding and handling, charging of coke ovens, pushing the coke from the ovens, and coke quenching. Gaseous emissions occur during the following operations: charging the coke ovens, the coking cycle, and subsequent combustion of coke-oven gases.

Open-Hearth Furnace Steelmaking. Particulates are the primary emissions from open-hearth-furnace operations. Emissions of iron oxide occur during the time the scrap is melted and large quantities of iron, silicon, and manganese oxides are formed and carried into the exhaust system of the furnace where high-purity oxygen is blown into the steel bath to remove the carbon. Gaseous emissions are largely carbon dioxide, but sulfur oxides may result through use of sulfur-containing fuels. If the scrap used in the charge contains combustibles, greater volumes of gaseous contaminants will be produced.

Basic-Oxygen Furnace Steelmaking. Particulates and carbon monoxide are major emissions in BOF steelmaking. Particulate emissions occur at the hot-metal transfer stations, the flux and alloy material-handling and transfer points, and the BOF vessel. Carbon monoxide and carbon dioxide are emitted at the BOF vessel.

Electric-Arc Furnace Steelmaking. Particulates are the primary emissions released by electric-arc furnace steelmaking. Charging, scrap melting, oxygen blowing, and tapping are major sources of particulate emissions. Blowing the molten steel with high-purity oxygen produces the highest emission rates. Emissions from the scrap charge and other operations are similar to those from other steelmaking processes and constitute the larges portion of the total emissions.

Control Technology and Costs. The following paragraphs contain a brief analysis of pollution control methods used in each process of the iron and steel industry.

Sintering Plants. Electrostatic precipitators, high-energy scrubbers, and baghouses are used to control the particulates originating from the sinter strand. Dry cyclones and baghouses are used to control particulates from other emission sources. Developments in blast-furnace technology which require additions of limestone and dolomite to the sinter mix make continued use of electrostatic precipitators problematical because of the difference in electrical properties between limestone dusts and iron-containing dusts. Installation of high-energy wet scrubbers may be required as replacements for some existing electrostatic precipitator installations.

Coke Plants. The technology for controlling emissions from coke ovens is still in the developmental stage; definitive control measures have not been established. Scrubbers are being used as the principal control technique for particulates in the control systems now under development. In addition to air-pollution-control devices, improved coke oven design and improved operating practices (such as sequence charging) are factors offering significant means of control.

Open-Hearth-Furnace Steelmaking. Electrostatic precipitators and high-energy scrubbers are used in controlling emissions from open-hearth furnaces.

Basic-Oxygen Furnace Steelmaking. Electrostatic precipitators and high-energy scrubbers are the principal control systems applied to the BOF. Baghouses have been suggested for use in the United States and have been tried in Europe. Baghouses are used for collecting particulates at the hot-metal stations, and the flux and ferroalloy handling locations.

Table 3-17-1 shows the estimated growth of the steel industry in terms of sales, production, and capacity in SEAS. It is estimated that the open-hearth process of making steel will decline in importance as the basic oxygen and electric-arc processes increase in importance.

The most recent analysis of costs for this sector was provided to the Agency by Temple, Barker & Sloane, Inc.,(TBS)[1]. This analysis was conducted in somewhat greater depth than, and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure, and is considered to be more precise. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The TBS estimates are as follows (in million 1975 dollars):

	75-77	75-83
Incremental Investment	2,100	3,300
Incremental O&M	200	2,300

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Principal reasons for differences between these cost estimates and the newer data are that TBS estimates are based on 1983 capacity while SEAS is based on 1972 production levels. There are also substantial differences in industry definition between the two studies.

Estimates from the earlier SEAS calculations are presented in Table 3-17-1. The TBS study includes costs associated with fugitive emissions and "other air." SEAS confines its analysis to stack emissions. Fugitive emissions account for 40 percent of capital expenditures in 1975-1983 for the TBS study. TBS credits the 1974 Cost of Clean Air Report as being a basis for the stack emission control costs of $1.65 billion over 1975-1983. SEAS forecasts a total figure of $3.33 billion for meeting the standards by 1979. In many instances, control of fugitive emissions may be necessary for plants to meet air quality standards. To the extent that such control is necessary, the SEAS forecasts tend to underestimate total control costs. The assumed phasing of expenditures has almost half of this occuring before 1975, with a resultant estimate of $1.80 billion in 1975-1979. This includes costs associated with expansion. Allowing for expansion costs to 1983 gives a figure of $2.27 billion. SEAS also bases its calculations upon research done for the 1974 Cost of Clean Air Report with revisions and modifications to assumptions by the same group that did the original Clean Air Report computations. Thus, much of the differences between the SEAS figures and those of TBS can be attributed to differences in assumed growth patterns and phasing of capital expenditures.

[1] "Economic Analysis of Proposed and Interim Final Effluent Guidelines, Integrated Iron and Steel Industry", Temple, Barker & Sloane, Inc., March, 1976.

Table 3-17-1.
Iron and Steel Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (1,000 MT/Yr)	131,879	140,159	136,358

Annual Growth Rate Over the Period 1976-85 = 0.94%

PROCESS CHARACTERISTICS	Segment	Model Plant Sizes (1,000 MT/Yr)	Control Technology	Standard
1. Sintering (alternatives)	1	508;1,100;2.700; 5.250	ESP	Pennsylvania
(alternatives)	2	500	Flooded Disc Scrubber	Pennsylvania
	3	575	ESP	Illinois
	4	500	Flooded Disc Scrubber	Illinois
	5	422;1,100;2,375; 3,600;5,200	ESP	Federal
	6	550	Flooded Disc Scrubber	Federal
	7	1,300	Baghouses	Federal
2. Coking (sequential)	1		CO gas desulfurization	H_2S Federal
	2		Charging Car Collector	Federal
	3		Collection Hood	Federal
3. Open Hearth	1	2,000;3,375	ESP	Pennsylvania
	2	125;150	ESP	California
	3	1,250	ESP	Illinois
	4	500;750;1,500; 2,000;3,500	ESP	Federal
	5	1,250;2,500	Scrubber	Federal
4. Basic Oxygen	1	1,125;2,333	ESP	Pennsylvania
	2	875;2,325	Scrubber	Pennsylvania
	3	1,440	ESP	California
	4	965	ESP	Illinois
	5	1,633;1.500;2.265: 3,500	ESP	Federal
	6	3,000;2,575;4,050	Scrubber	Federal

Table 3-17-1. (Continued)
Iron and Steel Industry Data Summary

5. Electric Arc	1	64;120;185;272; 400,800	Baghouse	Pennsylvania
	2	200;350;488	Building Evacuation	Pennsylvania
	3	1,000	Scrubber	Pennsylvania
	4	80;102;160	Baghouse	California
	5	108;575	Building Evacuation	California
	6	187;350;600;725	Baghouse	Illinois
	7	1,000	Scrubber	Illinois
	8	69;108;175;338;463 750;1,177	Baghouse	Federal
	9	100;350	Building Evacuation	Federal
	10	300;477;1,200	Scrubbers	Federal
	11	450	ESP	Federal

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
Particulates					
1971 Controls:	633.58	840.86	889.34		
Open Hearth	156.64	136.07	56.38		
BOF	444.62	653.58	764.04		
Electric-Arc	32.32	51.21	68.92		
Legislated Controls:	186.52	19.67	18.20		
Open Hearth	45.18	3.06	1.10		
BOF	132.00	15.41	15.69		
Electric Arc	9.34	1.20	1.41		
CONTROL COSTS (Million 1975 $)					
Investment	1,091.86	36.00	4.52	3,551.84	1,193.19
Total Annual	429.01	626.81	652.53	6,961.31	6,087.11
Capital	345.32	492.62	517.95	5,467.79	4,789.28
O&M	83.69	134.18	134.58	1,493.52	1,297.83

IRON FOUNDRIES INDUSTRY

Production Characteristics and Capacities. Iron foundries may be found in almost all urban areas. The economies of scale for the industry do not prohibit the continued existence of relatively small foundries. Because many of the foundries are operated in conjunction with steel making facilities, iron foundries tend to be concentrated in the major steel producing states: Pennsylvania, Ohio, Michigan, Illinois, and Alabama.

Iron foundries range from primitive, unmechanized hand operations to modern, highly-mechanized operations. Captive plants (owned or controlled by other businesses) are more likely to be mechanized and better equipped with emission-control equipment than are noncaptive plants.

In 1973, about 6 percent of the 1,432 plants were classified as large (over 500 employees), 29 percent as medium (100 to 500 employees), and 65 percent as small (less than 100 employees).

The major markets for iron castings include motor vehicles, farm machinery, and industries that build equipment for the construction, mining, oil, metalworking, and railroad industries. Captive plants have the capability of economical production of large lots of closely related castings. Most of the largest plants are captive and do not generally produce for the highly competitive open market.

Castings for machine parts, automotive parts, and soil pipe are produced from both pig iron and scrap. Cupola, electric-arc, electric-induction, and reverberatory furnaces are used. In 1973, 79 percent of the production was by cupolas, 12 percent by electric-arc furnaces, and the remainder by induction and reverberatory furnaces. The latter two types emit relatively small quantities of pollutants and require little or no emissions-control equipment.

The cupola furnace is a vertical, cylindrical furnace in which the heat for melting the iron is provided by injecting air to burn coke which is in direct contact with the charge. An electric-arc furnace is an enclosed, cup-shaped refractory shell that contains the charge. Three graphite or carbon electrodes extend downward from the roof. An electric arc between the electrodes and the charge generates the required heat. The cupola melts the charge continuously, while the arc furnace operates in a batch mode.

Emission Sources and Pollutants. Emissions from cupolas are carbon monoxide, particulates, and oil vapors. Particulate emissions arise from dirt on the metal charge and from fines in the coke and limestone charge. Hydrocarbon emissions arise primarily from partial combustion and distillation of oil from greasy scrap charged to the furnace, but their control is not costed in this report because the emissions are small. Arc furnaces produce the same kind of emissions to a lesser degree because of the absence of coke and limestone in the charge.

The particulate emission factor for uncontrolled cupola operation is taken to be 8.5 kg per metric ton. The best available estimate of the particulate emission factor for uncontrolled arc furnaces is taken to be 5 kg per metric ton.

An uncontrolled cupola generates approximately 150 kg carbon monoxide per metric ton of charge. Half of this carbon monoxide burns in the stack. On this basis, the estimated emission factor for carbon monoxide discharged from an uncontrolled cupola is approximately 75 kg per metric ton of charge. Uncontrolled arc furnaces produce negligible quantities of carbon monoxide.

Control Technology and Costs. In industrial practice, large cupolas use high-energy scrubbers to control the emission of particulates to acceptable levels. Medium sized cupolas can use either a high-energy scrubber or a baghouse. For small cupolas and arc furnaces, baghouses are preferred.

High-energy scrubbers usually are operated at a particulate collection efficiency of 95 percent. This efficiency can be increased to 99 percent by increasing the pressure drop. Fabric filters (baghouses) have an efficiency of 98 percent. Electrostatic precipitators also have a high efficiency rate of 96 percent.

Afterburners are used to control carbon monoxide emissions from cupolas. The efficiency of afterburners to control carbon monoxide emission is generally taken to be 94 percent.

Table 3-18-1 presents annualized production and cost control data for the industry; iron castings are made using either the cupola or electric-arc process. To estimate the costs of controlling air pollution from this industry, the five processes were listed individually for cost-comparison evaluation.

Table 3-18-1.
Iron Foundries Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (Million MT/Yr)	36.25	41.98	44.58

Annual Growth Rate Over the Period 1976-85 = 3.16%

PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Yr)	Pollutants Controlled	Control Technology
Process 1 - Cupola	87,000;13,060;2,180	Carbon Monoxide	Afterburners
Process 2 - Cupola	87,000	Particulates	Scrubber
Process 3 - Cupola	13,060;2,180	Particulates	Baghouse
Process 4 - Arc Furnace	13,060;2,180	Carbon Monoxide	Afterburners
Process 5 - Arc Furnace	13,060;2,180	Particulates	Baghouse

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	90.93	119.48	129.80		
Carbon Monoxide	1,171.81	1,539.83	1,672.83		
Legislated Controls:					
Particulates	47.93	21.12	2.61		
Carbon Monoxide	637.00	313.74	100.75		
CONTROL COSTS (Million 1975 $)					
Investment	86.85	16.66	2.94	509.66	188.48
Total Annual	154.00	241.25	232.62	2,599.24	2,258.09
Capital	52.27	79.22	82.95	867.16	749.08
O&M	101.73	162.03	149.67	1,732.07	1,509.01

STEEL FOUNDRIES INDUSTRY

Production Characteristics and Capacities. Two types of steel are produced from steel foundries: carbon steel castings and alloy-stainless steel castings, carbon steel representing 90 percent of the productive capacity. The electric-arc furnace is the established equipment for the melting of steels that are subsequently poured into molds to make castings. Castings may be in a semi-finished form that requires considerable machining before it can be used in other components, or it may be a high quality product that requires a minimum of additional work before subsequent use. Production of steel castings closely parallels the production of steel.

In determining control costs, the foundries producing large castings were grouped with the foundries producing carbon-steel castings on a one-shift basis.

Emission Sources and Pollutants. Particulates comprise almost 100 percent of the emissions occurring during the production of steel for castings. Minor amounts of carbon monoxide, nitrogen oxides, and hydrocarbons may be emitted. Most of the particulate emissions, which occur during the charging operation, are carried upward by the thermal gas currents created by the hot furnace; these emissions are generated during the charging operation and are the most difficult to control.

Control Technology and Costs. The allowable emissions of particulates per unit of process weight per hour under State Implementation Plans (Pennsylvania standards used as typical) and Federal New Source Performance Standards for electric arc steelmaking were used as guidelines in establishing the level of control likely to be required for electric-arc furnace steel foundries, and the subsequent costs.

Baghouses are the only reported means for the control of emissions from steel foundry electric-arc furnaces. One of the probable reasons for not using scrubbers or electrostatic precipitators is the lack of space for installing the required water treatment facilities in the case of scrubbers, and a reluctance on the part of the smaller foundry operators to get involved with electrostatic precipitators

The inventory of electric-arc furnace steel foundries used in the report is based on information in two foundry directories and information in the published literature. A few steel foundries still use open hearth furnaces but these are rapidly being phased out of use.

Development of control costs for steel foundries is complicated by several factors: foundries do not operate the same number of hours during the year, different furnaces sizes are used in a single plant, some foundries specialize in plain-carbon steel castings, and some foundries produce only those castings that can be produced in large production runs, while a small number produce large, complicated castings on a one-or two-shift basis. Table 3-19-1 shows the annualized summary information for steel foundries.

Table 3-19-1.
Steel Foundries Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (Million MT/Yr)	1,724.0	1,998.0	1,981.0

Annual Growth Rate Over the Period 1976-85 = 2.78%

PROCESS CHARACTERISTICS	Model Plant Sizes (1,000 MT/Yr)	Pollutants Controlled	Control Technology
Carbon/Alloy	5,583	Particulates	Baghouse

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	27.39	36.82	37.68		
Legislated Controls:					
Particulates	15.57	8.76	0.82		
CONTROL COSTS (Million 1975 $)					
Investment	3.39	3.03	0	269.23	18.72
Total Annual	43.28	47.50	48.06	580.66	468.60
Capital	40.77	43.21	43.82	535.33	428.26
O&M	2.51	4.29	4.24	45.33	40.34

PRIMARY ALUMINUM INDUSTRY

Production Characteristics and Capacities. The domestic primary aluminum industry is presently comprised of 12 companies operating 31 reduction facilities in 16 states. Three companies, Alcoa, Reynolds, and Kaiser, operate about two-thirds of the total capacity. Plants tend to be located in areas where cheap electrical power is available. The plant-size distribution for the industry is as follows:

Size Range (1,000 Metric Tons/Year)	No. Plants	Capacity(%)
0-90.7	6	8.8
90.8-136	11	28.1
136.1-190	8	30.8
191-254	6	32.3
	31	100.0

Aluminum is one of the most abundant of the elements and when measured either in quantity or value, its use exceeds that of any other primary metal except steel. It is used to some extent in virtually all segments of the economy, but its principal uses have been in transportation, building and construction, electrical industry, containers and packaging, consumer durables, and machinery and equipment. Growth rate of aluminum industry in the United States has averaged 7 percent in recent years.

Bauxite ore (typically containing 50-55 percent alumina) is the principal source of aluminum. Alumina is extracted from bauxite by any one of a number of variations of the Bayer process. In turn, alumina is dissolved in molten cryolite and reduced to aluminum by electrolysis in the universally-used Hall-Heroult aluminum reduction cells, which are connected in series to form a potline.

The aluminum reduction plant may be classified according to the type of anodes used in the cells; there are two major types based on how they are replaced. Prebaked anodes are replaced intermittently, and Soderberg anodes are replaced continuously. In the Soderberg continuous system, an anode paste is continuously supplied to a rectangular metal shell suspended above the cell. As the anode shell descends, it is baked by the heat of the cell. The two types of Soderberg anodes use different support methods: a Vertical

Stud System supported on vertical current-carrying pins (studs), and a Horizontal Stud System supported by pins which are inclined slightly from the horizontal.

Emission Sources and Pollutants. All three alternative processes currently used to produce aluminum release particulates which must be controlled.

Of the three anode systems in use, prebaked, horizontal Soderberg, and vertical Soderberg, the vertical Soderberg system emits the lowest quantity of particulates, and the prebaked and horizontal Soderberg systems are higher in pollutant emissions. On the other hand, the prebaked system is easiest to control, the vertical Soderberg somewhat more difficult, and the horizontal Soderberg the most difficult to control, leading to a gradual phasing out of the latter two processes.

Control Technology and Costs. In this analysis, it was assumed that 98 percent control of particulates would be sufficient to comply with ambient standards in all cases. New sources are assumed to be of the prebaked process only, and it is further assumed that the New Source Performance Standards for fluorides will be met by the same control processes applied for particulate control at no additional cost. Assumed control processes for the three production processes are shown below:

Cell Type	Primary Control	Secondary Control
Prebaked	Primary Collection (Hoods and Ducting), Plus Fluidized-Bed Dry Scrubber	None Needed
Horizontal Soderberg	Primary Collection, Wet Electrostatic Precipitator, Spray Tower, or Fluidized-Bed Dry Scrubber (experimental)	Spray Screen and Water Treatment
Vertical Soderberg	Primary Collection, Wet-Electrostatic Precipitator or Spray Tower	Spray Screen and Water Treatment

Table 3-20-1 shows the estimated growth of primary aluminum production. Note that the prebaked anode process is the dominant one in existence now, and that all new plants are assumed to employ this process. Two new production processes, the Alcoa and the Toth, which are claimed to be essentially non-polluting, are now being investigated. If successful, costs for new sources beyond 1980 might be substantially lower than indicated.

Table 3-20-1.
Primary Aluminum Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (1,000 MT/Yr)	4,243	4,940	4,653

Annual Growth Rate Over the Period 1976-85 = 1.69%

PROCESS CHARACTERISTICS	Model Plant Sizes (1,000 MT/Yr)	Pollutants Controlled	Control Technology
Prebaked Anode	144	Particulates	Hoods and Ducting; Scrubber
Horizontal Soderberg	137	Particulates	Hoods and Ducting; Wet ESP; Scrubber
Vertical Soderberg	32	Particulates	Hoods and Ducting; Wet ESP

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
Particulates:					
1971 Controls:	49.22	65.49	63.90		
Prebaked Anode	33.41	50.61	53.76		
Horizontal Soderberg	12.67	11.97	8.17		
Vertical Soderberg	3.14	2.91	1.97		
Legislated Controls:	24.48	15.39	3.64		
Prebaked Anode	16.62	11.90	3.07		
Horizontal Soderberg	6.04	2.44	0.40		
Vertical Soderberg	1.82	1.05	0.17		
CONTROL COSTS (Million 1975 $)					
Investment	629.46	6.64	0.25	2,054.64	699.06
Total Annual	473.02	669.66	590.56	7,295.29	6,286.73
Capital	190.84	288.13	289.22	3,110.06	2,734.70
O&M	282.18	381.51	301.34	4,185.23	3,552.03

SECONDARY ALUMINUM INDUSTRY

Production Characteristics and Capacities. Aluminum has become one of the most important metals in industry; only iron surpasses it in tonnages used. Major uses of the metal are in the construction industry, aircraft, motor vehicles, electrical equipment and supplies, beverage cans, and fabricated metal products which include a wide variety of home consumer products. The automotive industry is a large user of secondary aluminum ingot.

Secondary aluminum ingot is produced to specification; melting to specification is achieved mainly by segrating the incoming scrap into alloy types. The magnesium content can be removed with a chlorine gas treatment in a reverberatory furnace.

For the purpose of this report, the secondary aluminum industry is defined as that industry which produces secondary aluminum ingot to chemical specifications from aluminum scrap and sweated pig. The industry is viewed as consisting of secondary aluminum smelters excluding primary aluminum companies, non-integrated fabricators, and scrap dealers.

Emission Sources and Pollutants. The most serious emission sources during secondary aluminum smelting are: the drying of oil borings and turnings, the sweating furnace, and the reverberatory furnace. Emissions from the drying process are vaporized oils, paints, vinyls, etc; the sweating furnace produces vaporized fluxes, fluorides, etc; and the reverberatory furnace emissions are similar to the other two plus hydrogen chloride, aluminum chloride, and magnesium chloride from the chlorine gas treatment used to remove magnesium. As of 1970, an estimated 25 percent of chlorination station emissions were controlled, and it is estimated that by 1980, 80 percent will be controlled.

The several processes that cause emissions during the operation of a reverberatory furnace must be understood to calculate control costs properly; they are:

- Emissions at the forewell. Secondary smelters charge scrap directly into the forewell of the reverberatory furnace, and any oil, paint, vinyl, grease, etc., on the scrap vaporizes. The emissions from the charging process vary greatly with the material charged. Quantitative data on forewell emissions or the need for control are not available and costs or possible costs cannot be estimated.

- Emissions from the bath. During the time the aluminum bath is molten, it is covered with a flux to protect it from oxidation.

- Emissions caused by chlorination. The magnesium content of aluminum can be reduced by chlorination, but chlorination produces chloride emissions. Particulate emissions from the chlorination process are 500 kilograms per metric ton of chlorine used. Maximum magnesium removal requires about 18 kilograms of chlorine per metric ton of aluminum which has an emission rate of 9 kilograms of particulates per metric ton of aluminum. Magnesium removal is practiced by plants representing 92 percent of the estimated industry capacity. A small portion of these plants use aluminum fluoride fluxing for magnesium removal rather than chlorine. This report assumes that control costs for these few plants are similar to those that use chlorination. Wet scrubbing is the usual means of controlling chlorination station emissions; recent innovations on a dry control process are being tested.

Control Technology and Costs. Dryer emissions are known to exist and in many cases are treated with afterburners; however, there is insufficient data relating to the drying operations to permit evaluations of possible costs that might be expended to meet air-quality specifications.

Sweating furnace emissions, fluoride from fluxes, organic materials, oils, etc., can be controlled by using afterburners, followed by a wet scrubber or baghouse, for which control costs have been reported. However, no data is available on the number, capacity, or location of sweating furnaces. Thus, realistic estimate of control costs cannot be made. Industry costs and operating data are included in Table 3-21-1.

Table 3-21-1.
Secondary Aluminum Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (1,000 MT/Yr)	1,022	1,361	1,635

Annual Growth Rate Over the Period 1976-85 = 5.80%

PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Yr)	Pollutants Controlled	Control Technology
Model 1	5,261;17,120;	Particulates	Wet Scrubber
Model 2	43,536	Particulates	Wet Scrubber
Model 3		Particulates	Wet Scrubber
Model 4		Particulates	Wet Scrubber

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	8.67	13.88	17.20		
Legislated Controls:					
Particulates	4.79	4.41	3.65		
CONTROL COSTS (Million 1975 $)					
Investment	12.74	1.49	0.72	35.69	11.83
Total Annual	5.98	9.48	10.92	103.39	91.85
Capital	3.11	4.36	5.04	48.23	42.59
O&M	2.87	5.12	5.88	55.16	49.26

PRIMARY COPPER INDUSTRY

Production Characteristics and Capacities. Copper is one of the most important of the nonferrous metals, surpassed only by iron in ore tonnage produced in the United States. Its extensive use depends chiefly upon its electrical and heat conductivity, corrosion resistance, ductility, and the toughness of its alloys. Mechanical properties (and sometimes special properties) are enhanced by alloying with zinc to form brass, with tin to form bronze, with aluminum or silicon to form the higher strength bronzes, with beryllium to form high strength-high conductivity bronzes, with nickel to form corrosion resistant alloys, and with lead to form bearing metals.

Principal users of copper include the electrical, electronic, and allied industries for manufacturing power transmission lines, other electrical conductors, and machinery. The automobile industry (radiators, wiring, and bearings) and building-construction industry (tubing, plumbing) are the second- and third-largest consumers of copper in the United States.

Copper ore is either surface or underground mined, concentrated by ore-beneficiation techniques, then sent to the smelter. Processing of copper concentrates at a smelter involves the following operations. Roasting is normally used to dry the finely ground concentrates and to remove some sulfur, arsenic, antimony and selenium impurities. Roasting is frequently bypassed in modern smelters because better concentration methods remove free pyrite and permit the substitution of simple dryers for roasters at some smelters. The roasted concentrate is treated in a reverberatory furnace to produce an intermediate material called matte, which nominally contains copper, iron, and sulfur. The matte is converted to impure blister copper by blowing with air of an air-oxygen mixture in a vessel called a converter to remove the sulfur and the iron. Removal of the impurities from blister copper is sometimes limited to fire refining, in which the impurities are removed in a furnace by volatilization and oxidation. More often, it entails a two-step procedure: fire refining to produce electrodes for further refining by electrolytic methods.

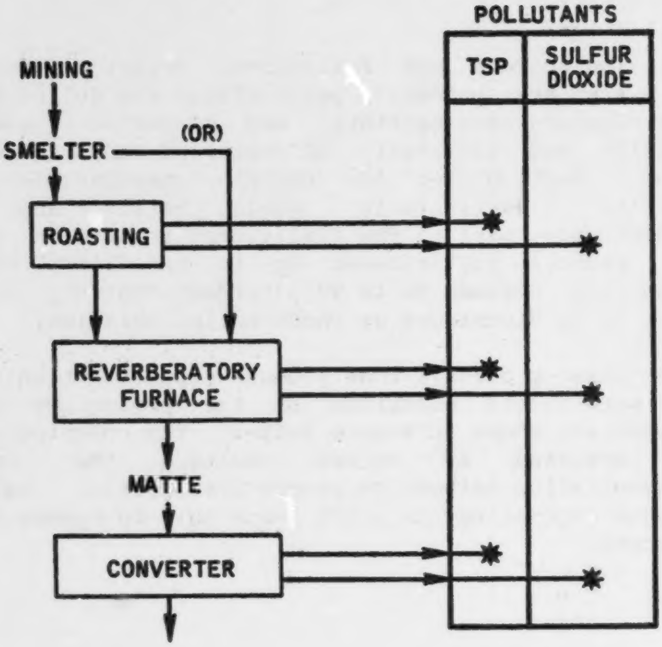
The principal sectors of the primary copper industry (mining, smelting, refining, fabricating and marketing) are dominated in varying degrees by three large, vertically-integrated companies. The plant size distribution for 15 active smelter operations, based on equivalent roaster charge, is shown in the tabulation below:

Capacity Range (1,000 metric tons/year)	No. Plants
0-181	1
182-363	4
364-544	4
545-816	3
817-907	3

Emission Sources and Pollutants. Emissions from coppper smelters are primarily particulates and sulfur oxides from the roaster, reverberatory, and converter furnaces. The density and continuity of emissions vary with the furnace type. Particulates can contain considerable byproduct credits, particularly noble metals and selenium. Accordingly, part of the traditional production process is to recycle particulates up to the limit of economic viability, between 90 to 99.5 percent control, leaving the rest to be discharged as uncontrolled emission.

The three processes that produce significant sulfur dioxide and particulate emissions in the production of primary copper are shown in Figure 3-22-1. The roasting process may be bypassed by modern smelters that have better concentration methods to remove free pyrite. Half of the plants operating in 1971 were able to bypass the roaster process.

Figure 3-22-1.
Primary Copper Production Processes



Sulfur dioxide is emitted from all three smelter operations; however, the concentration of sulfur dioxide in the gases varies considerably among the three. Sulfur dioxide concentrations for fluid-solid roasters, reverberatory, and converter furnaces are 6-10 percent, 0.50-2 percent, and 2-5 percent by volume, respectively.

Control Technology and Costs. In 1971, approximately 95 percent of the particulate emissions were being controlled from copper smelters because of the economic advantage of recovering precious metals. Further removal of particulates is required to allow the sulfur dioxide control devices to operate effectively.

It is assumed that most smelters will manufacture sulfuric acid by the contact process from the sulfur dioxide in the roaster and the converter gases. Two major conditions must be met: (1) the concentration of sulfur dioxide in the gas stream should be at least 4 percent by volume, and (2) the gas must be practically free of particulate matter to avoid poisoning the catalyst in the acid plant. Eleven smelters already have acid plants. The one plant in Michigan does not require an acid plant beause of the low sulfur content of the ore, and therefore it is not costed out in this report.

Several methods have been proposed and have been considered here for the purpose of removing the sulfur dioxide from the reverberatory gas stream. These include:

- Absorption of sulfur dioxide in dimethylaniline, followed by desorption and recovery.
- Cominco absorption process in which sulfur dioxide is absorbed into an ammonium sulfite solution, which yields concentrated sulfur dioxide and an ammonium sulfate by-product.
- Wet lime scrubbing, whereby the reverberatory furnace gases are scrubbed in a slurry of lime and water.
- Wet limestone scrubbing, essentially similar to wet lime scrubbing except a slurry of limestone is used as the scrubbing medium.

Annualized control costs and industry operating statistics are detailed in Table 3-22-1.

Table 3-22-1.
Primary Copper Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (Million MT/Yr)	9.06	10.55	10.26

Annual Growth Rate Over the Period 1976-85 = 2.62%

PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Yr)	Pollutants Controlled	Control Technology
Roaster	704,000	SO_2 & TSP	Acid Plant
Reverberatoy Furnace or		SO_2 & TSP	Limestone Scrubber
Convertor	400,000;501,400	SO_2 & TSP	Acid Plant

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Sulfur Dioxide	2,032.58	2,966.87	3,011.89		
Particulates	56.73	82.81	84.06		
Legislated Controls:					
Sulfur Dioxide	1,105.54	475.71	98.42		
Particulates	26.41	3.79	2.72		
CONTROL COSTS (Million 1975 $)					
Investment	267.78	25.13	0	1,210.89	378.67
Total Annual	210.75	319.18	318.57	3,407.30	2,954.45
Capital	135.44	195.72	196.97	2,103.11	1,817.81
O&M	75.31	123.46	121.60	1,304.19	1,136.63

SECONDARY BRASS AND BRONZE INDUSTRY

Production Characteristics and Capacities. The secondary brass and bronze industry may be divided into two segments: ingot manufacturers and brass mills. Both segments of the industry charge scrap into a furnace where it is melted and alloyed to meet design specifications for chemical composition. Ingot manufacturers use either a stationary reverberatory furnace or a rotary furnace for most of their production. Small quantities of special alloys are processed in crucible or electric induction furnaces. A few cupolas exist in which highly oxidized metal, such as skimmings and slag, is reduced by heating the charge in contact with coke. Ingot manufacturing invariably requires injection of air to refine the scrap. Brass mills use scrap that does not require such extensive refining; the channel induction furnace is the most common type used in these mills.

The number of ingot manufacturing furnaces in existence in 1972 was calculated to be 122. Of these furnaces, 13 were large, 29 were medium, and 80 were small. The large furnaces produced 50 percent of the total annual ingots, while the medium furnaces produced 30 percent, and the small furnaces produced 20 percent.

The capacity of channel induction furnaces for brass mills ranges from 0.5 to 5 metric tons, with smaller furnaces being the most common. It was estimated that there were 35 plants in existence in 1973 with an average of 3.7 furnaces per plant, or a total of 130 furnaces.

Emission Sources and Pollutants. Metallurgical fumes containing chiefly zinc oxide and lead oxide are the major emissions from the reverberatory and rotary furnaces that are used by ingot manufacturers and from the induction furnaces that are used by the brass mills. Fly ash, carbon, and mechanically-produced dust are often present in the exhaust gases, particularly from the furnaces used by the ingot manufacturers. Zinc oxide and lead oxide condense to form a very fine fume which is difficult to collect.

Control Technology and Costs. Ingot manufacturers use fabric-filter baghouses, high-energy wet scrubbers, and electrostatic precipitators because of their high efficiency in collecting the fine zinc oxide fumes; 67 percent use a baghouse, 28 percent use a scrubber, and 5 percent use an electrostatic precipitator.

The collected dust was assumed to have a value of 10 cents per kilogram, and an average collector efficiency of 97.5 percent. This value of collected dusts was applied as a credit to control costs.

Fabric filter baghouses are used on the brass induction furnaces to collect the particulates. Investment and annual costs were obtained from three plants that use furnaces with capacities ranging from 22 to 32 metric tons per day. The average value for the three plants was used for the model furnace of 25 metric tons per day. No credit for collected dust is assumed for brass mills.

Annualized control costs and industry operating statistics are detailed in Table 3-23-1.

Table 3-23-1.
Secondary Brass and Bronze Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985		
Capacity (Million MT/Yr)	0.959	1.152	1.196		
Annual Growth Rate Over the Period 1976-85 = 3.68%					
PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Yr)		Pollutants Controlled		Control Technology
Model 1	716		Particualtes		Fabric Filter
Model 2	2,966		Particulates		Fabric Filter
Model 3	6,105		Particulates		Fabric Filter
Model 4	11,020		Particulates		Fabric Filter
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	5.21	7.94	8.58		
Legislated Controls:					
Particulates	2.57	0.51	0.54		
CONTROL COSTS (Million 1975 $)					
Investment	5.16	0.54	0.07	21.17	6.29
Total Annual	4.94	7.28	7.08	78.03	67.53
Capital	1.96	2.78	2.78	29.70	25.58
O&M	2.99	4.50	4.30	48.33	41.94

PRIMARY LEAD INDUSTRY

Production Characteristics and Capacities. Lead production in the United States involves three major steps: mining, crushing, and grinding of sulfide ores, and benefication to produce lead concentrates; smelting of the concentrates by pyrometallurgical methods to produce impure lead bullion; and refining the bullion to separate other metal values and impurities.

The U.S. primary lead industry has some 80 small mining companies in 14 states who mine and mill their own concentrates; some of the smaller mines utilize custom mills. Smelting and refining of lead in the United States is done by four companies (Asarco, St. Joe, Amax, and Bunker Hill) that operate six smelters and five refineries. St. Joe is the only company not involved in custom smelting (outright purchase of concentrates) or toll smelting (smelting of concentrates for a fee).

Battery components accounted for 46 percent of the 1.40 million metric tons of lead consumed in 1973. Gasoline antiknock additives accounted for 16 percent, pigments 7 percent, ammunition 5 percent, solder 4 percent, cable covering 3 percent and miscellaneous metal products, such as castings, weights, and ballast, the remainder.

Emission Sources and Pollutants. Emissions from lead smelters are primarily particulates and sulfur dioxide from two sources: sintering machines and blast furnaces. Most of the sulfur dioxide is removed in the sintering machine; the density of emissions varies with the source.

Flue-gas particulates include the following metals: as high as 30 percent lead, and traces of zinc, antimony, cadmium, and copper. In Western smelters, often significant byproduct credits of noble metals are also emitted; in one case, over 30 ounces of silver per ton and 0.14 ounce of gold was recovered. Thus, there is an economic reason to recover particulates in addition to fume control. The emissions from the slag furnaces used in the Western smelters to recover zinc also include particulates containing zinc oxide and zinc dust.

Control Technology and Costs. Sulfur oxides and particulates in sintering machine off-gases are being controlled by the use of sulfuric acid plants in three of the six U.S. smelters. In these smelters, particulate control is required for effective operation of the acid-plant system. In the three U.S. smelters without acid plants, most of the particulates in the processing off-gases are removed from the cooled off-gases in a baghouse prior to the stack; sulfur oxide in the off-gases is not controlled. One of these smelters has an acid plant which is used only on the off-gases from a copper converter in an adjoining plant.

Each of the six U.S. plants was examined in terms of equipment required to bring the plant within Federal ambient standards. Acid plants were assumed for those plants which do not now control sulfur oxide emissions. Methods of metallurgical operation at all six plants are similar, the differences stem from the type of ore handled by the three Missouri smelters and by the three Western smelters. In the West, lead ore concentrates are leaner with much higher amounts of gold, silver, zinc, cadmium, copper, antimony, and arsenic present. Except for a slagfuming furnace operation in the Western smelters to remove the higher amounts of zinc in the concentrates, there are no major differences in the basic smelter operations. There is a difference in degree in the refining operations, but off-gases are not a problem in the refineries. Refining involves kettle operations at low temperatures just above the melting point of lead; no fumes are produced.

To determine control costs, the following sequences were assumed. The feed has a sulfur content of 15 percent, of which 85 percent is removed as sulfur dioxide in the sinter step. Particulate emissions are 54.5 kg/ton of feed in the sinterer, and 13.6 kg/ton of feed in the blast furnace.

Sulfur dioxide from the sinter step is available for conversion into acid. The acid plant is assumed to convert 90 percent of the sulfur dioxide it receives, emitting the rest. With an acid plant on the sinter, the additional gas cleaning scrubber is assumed to remove 90 percent of particulates. The results of these calculations are presented in Table 3-24-1 along with anticipated emission levels.

Table 3-24-1.
Primary Lead Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (1,000 MT/Yr)	358.6	402.4	439.4

Annual Growth Rate Over the Period 1976-85 = 3.43%

PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Yr)	Pollutants Controlled	Control Technology
Blast Furnaces, Sintering	107,026; 130,608	SO2; Particulates	Acid Plant

EMISSIONS (MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates (Lead)	331	503	552		
Sulfur Oxides	102,685	156,062	171,338		
Legislated Controls:					
Particulates (Lead)	280	252	276		
Sulfur Oxides	69,308	41,417	45,235		
CONTROL COSTS (Million 1975 $)					
Investment	10.75	1.94	0.54	47.50	13.56
Total Annual	7.90	11.46	12.21	125.24	107.26
Capital	5.52	7.17	7.73	80.05	68.78
O&M	2.37	4.29	4.49	45.19	38.48

SECONDARY LEAD INDUSTRY

Production Characteristics and Capacities. The secondary lead industry is defined as the industry that recovers lead or lead alloys by smelting and/or refining lead scrap; this does not include the activities of scrap dealers who may sweat lead. A total of 22 companies in the secondary lead industry operate 45 plants. The two leading producers are estimated to account for about 64 percent of lead production.

Approximately 526,000 metric tons of secondary lead were recovered from scrap in 1970. In 1971, production rose to 528,000 metric tons. By 1973, the production of secondary lead rose to approximately 577,000 metric tons.

The assumption of an average emission factor for cupolas and reverberatory furnaces allows the breakdown of the secondary lead industry on the basis of capacity alone. Available capacity data indicate three model plant sizes. The estimated industry capacity and model plant data are given in the following tabulation:

	Capacity Range (metric tons/day)	No. Plants	Total Capacity (metric tons/day	Model Plant Capacity (metric tons/day
Plant Model I	83-181	23	2,482	109
Plant Model II	27-82	6	327	54
Plant Model III	12-26	16	253	15.8
Totals	12-181	45	3,062	

Emission Sources and Pollutants. Emission of particulates occurs from lead-processing furnaces. Generally, about 67 percent or more of the output of the secondary lead industry is processed in blast furnaces or cupolas that are used to reduce lead oxide in the form of battery plates or dross, to lead. If oxide reduction is not needed, then lead scrap can be processed in reverberatory furnaces. Kettle or pot furnaces may be used to produce small batches of alloys for holding or refining lead. These lead processing furnaces represent obvious particulate emission sources; the primary emissions being lead oxide. Another particulate emission source is the slag tap and feeding ports on the cupolas and reverberatory furnaces. Although lead is occasionally sweated in a reverberatory furnace, reclamation of secondary lead by this means is a very small portion of the total lead production. Emissions from slag operations are not known.

The industry estimate of 90 percent net control in 1970 indicates that nearly all plants had emission controls of some sort. A control increase to 98 percent estimated by 1980 is based on implementation of the proposed new source performance standards.

Control Technology and Costs. Either a baghouse or a wet scrubber can be utilized to achieve emission control. The baghouse is chosen for this cost analysis because it is generally cheaper; it is assumed baghouse life averages 15 years.

Annual costs include capital charges, operating and maintenance, and credits for byproduct recovery value. Since the lead oxide collected in the control equipment is recycled into the smelting furnace, it has value as a byproduct; therefore, the recovery of this lead oxide lowers estimated operating and maintenance costs.

The calculated costs for Model I, II, and III plants presented in this model plant cost tabulation included in Table 3-25-1 were based on the following key points:

- Model I plants are assumed to require two separate baghouse installations, while Model II and Model III were assumed to need only one baghouse for control.
- Baghouse airflow needs were estimated at 11.2 cubic meters per ton of daily capacity.
- The value of lead oxide recovered from baghouse operations was estimated to be 5 cents per kilogram, plus 50 percent. It was further assumed that only the lead oxide recovered by going from 90 percent net control in 1970 to an estimated 98 percent net control in 1980 should be credited against control costs. This amounts to 6.17 kilograms per ton of lead processed. In addition, production at full capacity was assumed.

Table 3-25-1.
Secondary Lead Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985		
Capacity (MT/Day)	3,206.2	3,598.6	3,929.0		
Annual Growth Rate Over the Period 1976-85 = 3.44%					
PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Day)	Pollutants Controlled		Control Technology	
Secondary Lead	15.8;54;109	Particulates		Fabric Filter	
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	3.73	5.68	6.23		
Legislated Controls:					
Particulates	2.35	1.14	1.52		
CONTROL COSTS (Million 1975 $)					
Investment	0.71	0.62	0.19	6.33	4.57
Total Annual	1.10	2.29	2.77	23.94	21.62
Capital	0.26	0.88	1.21	8.77	8.29
O&M	0.83	1.40	1.55	15.16	13.33

PRIMARY ZINC INDUSTRY

Production Characteristics and Capacities. Zinc ranks after aluminum, copper, and lead in tonnage of nonferrous metals produced in the United States. Major uses in 1973 were zinc-base alloys, particulary die-cast alloys used in automotive and electrical equipment (41 percent), galvanized steel used in construction and electrical transmission equipment (36 percent), brass and bronze used for plumbing, heating, and industrial equipment (14 percent), zinc chemicals, particularly zinc oxide, used in the rubber, paint, and ceramic industries (4 percent), and rolled zinc used in dry cells and lithographic plates (2 percent).

The principal ore minerals are sulfides, which may be predominantly zinc ores or lead-zinc ores. Also, some zinc is obtained from lead-base and copper-base ores. Zinc sulfide concentrates produced from these ores are converted to the oxide state (calcine) by roasting, and then reduced to metallic zinc by either electrolytic deposition or by distillation in retorts or furnaces. In plants using distillation methods, the calcine is given an additional sintering step to provide a more compact feed as well as to remove impurities. Some zinc producing companies also produce zinc oxide. In pyrolytic plants, both zinc metal and zinc oxide are produced from zinc vapor; in the first case, the vapor is condensed to zinc metal; in the second, it is oxidized in a chamber.

Over three-quarters of the domestic mine production comes from these six states: Tennessee, Colorado, Missouri, New York, Idaho, and New Jersey. Numerous small companies participate in only the mining and beneficiation sector of the zinc industry; these companies sell their concentrates to custom smelters.

In 1973, six companies (St. Joe, Asarco, Amax, Bunker Hill, New Jersey Zinc, and National Zinc) operated eight primary zinc plants, all of which operate as custom smelters to some extent. Information on the locations, acid plant installations, annual capacities, and types of roasting processes used is also included. The three remaining horizontal-retort plants totaling 161,000 metric tons of capacity are in various stages of being phased out of operation. New electrolytic capacity totaling 354,000 metric tons of zinc will replace these horizontal retort plants; plant size distribution of the three new U.S. electrolytic plants is tabulated below.

Capacity Feed (metric tons/yr)	Capacity, Slab Zinc (metric tons/yr)	% of U.S. Capacity After Closing Horizontal Retort Plants
296,000	163,000	29
264,000	145,000	26
82,000	45,000	8

The main product of zinc reduction plants is slab zinc. Ore concentrate capacity in 1973 was 1,337,000 metric tons per year, equivalent to 763,000 metric tons slab zinc. Approximately 24 percent of this capacity utilizes horizontal retort plants; all of which are scheduled for phasing out in the near future.

In 1973, the three types of pyrothermic plants (electrothermic, vertical retort, and horizontal retort) accounted for almost two-thirds of the primary zinc capacity. This will change in the near future because three new electrolytic plants are in the early stages of construction; they are: the Asarco plant at Stephensport, Kentucky with a planned capacity of 163,000 metric tons of zinc annually, the New Jersey Zinc Company plant at Clarksville, Tennessee with a planned 145,000 metric tons capacity, and the New National Zinc plant at Blackwell, Oklahoma with a planned capacity of 45,000 metric tons.

Emission Sources and Pollutants. Emissions from zinc reduction plants are primarily particulates and sulfur dioxide from the roasters in the electrolytic plants, and from the roasters and traveling-grate sintering machines in the pyrothermic plants. In the electrolytic plants, the calcine from the roaster is substantially sulfur-free so that there is a heavy concentration of sulfur dioxide in the off-gases. In the case of the pyrothermic plants, roaster off-gases are also heavy, but there are only light concentrations of sulfur dioxide in the sintering machine off-gases. Particulates are relatively heavy in both streams.

Control Technology and Costs. Sulfur oxide and particulates in roaster off-gases are now being controlled by the use of sulfuric acid plants in six of the present eight plants. In these cases, particulate control necessary for the effective operation of the acid plant system is achieved with associated gas cleaning equipment. With the closing of the three horizontal retort plants, all the roasters in the primary zinc plants are controlled with acid plants. In the two remaining pyrothermic plants, the sintering machine particulates are controlled in one case by settling flues, electrostatic precipitators, and a baghouse, in the other, by a venturi scrubber.

In general, the control scheme for the primary zinc industry is to use acid plants on the roaster off-gases where most of the sulfur dioxide is given off. All other operations, with the exception of three plants using a horizontal retort, have particulate control devices. In the case of these plants with horizontal retorts, conversion to vertical retort equipment is the practical control scheme; however, costs for this conversion were not obtained, as this involves a major plant renovation.

With the closing of the three horizontal retort plants, the only new control equipment required for the industry is the acid plants and associated gas cleaning equipment necessary to control sulfur dioxide and particulates in the three new electrolytic plants under construction; these controls come under New Source Performance Standards.

Annualized control costs are detailed in Table 3-26-2.

Table 3-26-2.
Primary Zinc Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (1,000 MT/Yr)	1,024.0	1,200.0	1,283.0

Annual Growth Rate Over the Period 1976-85 = 3.46%

PROCESS CHARACTERISTICS	Model Plant Sizes (1,000 MT/Yr)	Pollutants Controlled	Control Technology
Roaster and Sinter;	42-226	Particulates (Zinc)	Acid Plant
Electrolytic	45-163	Sulfur Dioxide	

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates (Zinc)	29.69	42.14	46.18		
Sulfur Oxides	212.98	302.32	331.27		
Legislated Controls:					
Particulates (Zinc)	12.46	3.32	3.26		
Sulfur Oxides	98.17	34.54	30.39		
CONTROL COSTS (Million 1975 $)					
Investment	8.07	4.61	1.52	64.49	42.80
Total Annual	11.02	25.70	31.92	269.49	245.32
Capital	4.03	14.47	20.49	145.36	137.70
O&M	6.99	11.23	11.43	124.13	107.62

SECONDARY ZINC INDUSTRY

Production Characteristics and Capacities. Zinc ranks after aluminum, copper, and lead in tonnage of nonferrous metals produced in the United States. Major uses in 1973 were zinc-base alloys, particularly die-cast alloys used in automotive and electrical equipment (41 percent), galvanized steel used in construction and electrical transmission equipment (36 percent), brass and bronze used for plumbing, heating, and industrial equipment (14 percent), zinc chemicals, particularly zinc oxide, used in the rubber, paint, and ceramic industries (4 percent), and rolled zinc used in dry cells and lithographic plates (2 percent).

Secondary zinc comes from two major sources: the zinc-base alloys and the copper-base alloys. Most of the secondary zinc that is recovered comes from reconstituted copper-base alloys; slab zinc is next, then chemical products, and zinc dust. For purposes of this report, the 14 operating plants that comprise the secondary zinc industry use sweating and/or distilling operations to produce zinc slab, dust, and oxide solely from scrap. The secondary zinc industry is not considered to include the activities of:

- Primary zinc producers that may manufacture zinc from scrap and ore
- Secondary brass and bronze plants that recover zinc in copper alloys
- Chemical manufacturers that produce zinc compounds by chemical treatment of zinc scrap
- Scrap dealers that may sweat zinc.

The total secondary industry zinc slab capacity stood at 18,100 metric tons at the end of 1972. Redistilled secondary zinc slab production in 1971 was 73,400 metric tons, of that total 11,200 metric tons were produced by the secondary zinc industry and the remainder was produced by the primary zinc industry. Other zinc materials produced by the secondary zinc companies included zinc dust and zinc oxide. In 1971, slightly over 24,500 metric tons of zinc in the form of zinc oxide was produced from zinc scrap. It is assumed that nearly all of this oxide is produced by the secondary zinc companies and that this production is indicative of a secondary capacity of 31,700 metric tons per year of contained zinc. Statistics are not available for total secondary zinc dust and zinc oxide capacity; estimates were derived from the available data. To further complicate capacity estimation, some production set-ups permit production of either oxide or slab.

The production of zinc dust from zinc-base scrap in 1970 totaled 26,300 metric tons. It is assumed that much of this production came from the secondary industry and that secondary capacity is 31,700 metric tons per year.

No data is available for sweating capacity; which can be performed in various types of furnaces. It is assumed that much of the feed material for production of refined secondary zinc is sweated; sweating capacity is therefore placed at 63,500 metric tons per year.

Emission Sources and Pollutants. There are at least four operations which generate emissions in the secondary zinc industry: materials handling, mechanical pretreatment, sweating, and distilling. This analysis considers only control costs for emissions from the sweating and distilling operations, as insufficient data is available for calculating the possible costs of controlling emissions from the other sources.

In the sweating operation, various types of zinc containing scrap are treated in either kettle or reverberatory furnaces. The emissions vary with the feed material used and the feed material varies from time-to-time and from plant-to-plant. Emissions may vary from almost 0 to 15 kg of particulates per metric ton of zinc reclaimed. For purposes of this report, it is assumed that the maximum emission rate applies.

In the case of the various types of zinc distilling furnaces, the accepted emission rate is 23 kilograms per metric ton of zinc processed. Some distillation units produce zinc oxide, and normally utilize a baghouse for collection of the product. This report assumes that these baghouses are sufficient to meet national ambient standards. However, for the purpose of calculating control costs, it was assumed that essentially all of the estimated zinc oxide capacity could be switched to slab zinc or dust production, and emission controls would be required.

Controlled and uncontrolled emissions from secondary zinc sweating operations cannot be estimated with an acceptable degree of probable accuracy because reliable data are not available.

The estimated emissions from secondary zinc distillation based on available production estimates and an average emission factor of 23 kg per metric ton are tabulated below.

It is estimated that 57 percent of the emissions were controlled in 1971 and that 90 percent will be controlled in 1980.

Control Technology and Costs. The major emission of concern is particulates, consisting mainly of zinc oxide. Baghouses have been shown to be effective in controlling both distillation and sweating-furnace emissions except when the charge contains organic materials such as oils.

A complete accounting of secondary zinc plants by type of furnaces used and the product or products produced is not available. Based on the limited information, it is assumed that the industry's 14 plants can be represented by two models: two Model I plants, each consisting of 7,260 metric tons per year sweating capacity and 10,900 metric tons per year distilling capacity; and twelve Model II plants, each consisting of 4,080 metric tons per year of sweating capacity and 4,990 metric tons per year of distilling capacity.

Estimated annualized control costs for the secondary zinc industry are detailed in Table 3-27-1.

Table 3-27-1.
Secondary Zinc Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (1,000 MT/Yr)	85.83	100.63	107.56

Annual Growth Rate Over the Period 1976-85 = 3.46%

PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Yr)	Pollutants Controlled	Control Technology
Sweating and Distilling	12,800; 5,500	Particulates	Baghouse

EMISSIONS (MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	332.0	471.0	516.0		
Legislated Controls:					
Particulates	261.5	325.4	102.6		
CONTROL COSTS (Million 1975 $)					
Investment	0.28	0.14	0.03	2.52	1.32
Total Annual	0.56	0.98	1.06	10.45	9.19
Capital	0.16	0.31	0.33	3.15	2.78
O&M	0.40	0.67	0.73	7.30	6.41

ASBESTOS INDUSTRY

Production Characteristics and Capabilities. The asbestos industry consists of the following major activities: mining of ore, milling of ore, and the manufacture of asbestos products, all of which are used in thousands of products and applications. Over 40 percent of annual consumption, which was estimated to be nearly 750,000 metric tons in 1972, is used for construction materials, primarily cement products; other important users include floor tiles, paper, asphalt felts, friction products, and packing and gaskets. Domestic consumption has been growing at an annual rate of about 5 percent.

Asbestos is normally handled by air conveyance during processing. The air conveying system must be tightly controlled because of the adverse health effects of airborne fibers, which are kept airborne for significant distances as a result of their fine structure and low density. The finishing processes that involve breaking, grinding or polishing, which are required in making asbestos products, account for most of the air emissions.

A total of nine milling plants were in operation during 1970. Over 98 percent of milling capacity (about 149,000 metric tons) was represented by five large, vertically-integrated firms. Imports represented nearly 85 percent of the asbestos used in various manufacturing processes during 1973.

Manufacturing plants can be grouped into facilities producing the following types of general product categories: construction materials, floor tiles, felts and papers, friction products, textiles, and miscellaneous.

Emission Sources and Pollutants. Principal emission sources of asbestos are from the air conveying systems used in the processing and finishing stages required in making asbestos products. Asbestos emissions can be divided into two categories: either asbestos remains essentially a free fiber throughout the process and in the final product or the asbestos is wetted or bound into a matrix at an early stage of processing.

Production of asbestos textiles is the major manufacturing process in the first category. In this process, the long asbestos fibers are fluffed and then blended with a cellulosic fiber. The subsequent processing, which involves carding, lapping, roving, spinning, and weaving or braiding, is performed on equipment similar to the standard textile machining processes requiring frequent access when operating.

Virtually all other processes fall in the second category. Significant emissions may occur in finishing operations for cement pipe and building products, felts and papers, and friction products. Asbestos emissions from floor-tile manufacture are essentially nil after the fibers are mixed with the hot vinyl or asphalt. In friction products, the processes of molding and curing are usually pollution free, while the finishing processes involving shaping, cutting, and sawing may give rise to some emissions. In sprayed insulation, asbestos emissions occur from handling the dry asbestos and cement mixture, the escape of non-wetted fiber, overspray and splash, and the disposal of wastes.

Control Technology and Costs. The only acceptable control technique for asbestos milling and manufacturing is the fabric filter, or baghouse. Efficiencies of 95 percent or higher are relatively easily obtained. This process was assumed to be applied at all plants. Annualized control costs and industry statistics are detailed in Table 3-28-1.

Table 3-28-1.
Asbestos Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (1,000 MT/Yr)	924.28	1,227.84	1,274.57

Annual Growth Rate Over the Period 1976-85 = 3.75%

PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Yr)	Pollutants Controlled	Control Technology
Textile	608	Particulates	Baghouse
Miscellaneous	189	Particulates	Baghouse
Felt Friction	2,721	Particulates	Baghouse
Tiles	6,893	Particulates	Baghouse
Construction	3,592	Particulates	Baghouse
Milling	29,024	Particulates	Baghouse

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	53.09	71.41	79.42		
Legislated Controls:					
Particulates	25.04	2.95	1.59		
CONTROL COSTS (Million 1975 $)					
Investment	4.60	1.50	0.1	24.76	10.17
Total Annual	2.99	8.18	8.91	74.89	67.84
Capital	2.38	3.85	4.03	41.37	35.95
O&M	0.61	4.33	4.88	33.52	31.89

ASPHALT CONCRETE PROCESSING INDUSTRY

Production Characteristics and Capacities. Asphalt concrete includes a mixture of aggregates and an asphalt cement binder. Aggregates usually consist of different combinations of crushed stone, crushed slag, sand, and gravel. Asphalt concrete plant processing equipment includes raw-material apportioning equipment, raw-material conveyors, a rotary dryer, hot-aggregate elevators, mixing equipment, asphalt-binder storage, heating and transfer equipment, and mineral-filler storage and transfer equipment.

There are approximately 1,320 companies employing approximately 300,000 to operate 4,800 asphalt concrete plants in the United States. Plant size distribution is listed below; 60 percent of the capacity is located in plants having an average size of 182 metric tons per hour. Based on a 1972 survey conducted by the National Asphalt Pavement Association (NAPA) covering 1,081 plants, 76 percent were stationary plants and 24 percent were portable. Continuous mixers comprised 24 percent of the portable plants, compared with only 2 percent for stationary plants.

Size Range (metric tons/hr)	Average Size (metric tons/hr)	No. Plants	Capacity(%)
82-100	91	694	6.6
101-263	182	3,122	59.5
264-282	273	520	14.9
283-499	391	464	19.0
Totals		4,800	100.0

Asphalt concrete production is essentially a batch-type operation; continuous-mix represents only 10 percent of the industry.

Emission Sources and Pollutants. The predominant emissions are dust particulates from the aggregates used in making asphalt concrete. The largest sources of particulate emissions are the rotary dryer and screening, weighing, and mixing equipment. Additional sources that may be significant particulate emitters, if they are not properly controlled, are the mineral-filler loading, transfer, and storage equipment, and the loading, transfer, and storage equipment that handles the dust collected by the emission control system. Generally, the uncontrolled emissions from asphalt batching plants amount to 23 kg of dust per metric ton of product.

Control Technology and Costs. Practically all plants use primary dust collection equipment, such as cyclones or settling chambers. These chambers are often used as classifiers with the collected aggregate being returned to the hot-aggregate elevator to combine with the dryer aggregate load.

The gases from the primary collector must be further cleaned before venting to the atmosphere. The most common secondary collector is expected to be the baghouse, although venturi scrubbers are used in some plants. The baghouse allows dry collection of dust which can be returned to the process or dropped in a landfill. The venturi scrubber makes dust hauling expensive due to the wetting of the dust. Also, the use of large settling ponds and the possible need for water treatment discourage the use of venturi scrubbers.

Annualized control costs and industry capacities are detailed in Table 3-29-1.

Table 3-29-1.
Asphalt Concrete Processing Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985		
Capacity (MT/Hr)	1,118.71	1,072.71	1,115.88		
Annual Growth Rate Over the Period 1976-85 = 2.20%					
PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Hr)		Pollutants Controlled	Control Technology	
Type 1 Type 2	100,200,300,400		Particulates	Venturi Scrubbers Baghouse	
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	3,186.32	3,710.72	3,836.16		
Legislated Controls:					
Particulates	1,371.11	113.54	46.86		
CONTROL COSTS (Million 1975 $)					
Investment	199.81	24.42	2.21	664.19	161.49
Total Annual	201.06	289.05	300.62	3,211.09	2,782.90
Capital	81.81	103.89	108.03	1,181.97	1,011.30
O&M	119.24	185.16	192.59	2,029.12	1,771.61

CEMENT INDUSTRY

Production Characteristics and Capacities. Portland cement, which accounts for approximately 96 percent of cement production in the United States, is processed from a blend of various calcareous, argillaceous, and siliceous materials including limestone, shell, chalk, clay, and shale. As the binder in concrete, portland cement is the most widely-used construction material in the United States. The four major steps in producing portland cement are: quarrying and crushing; blending, grinding, and drying; heating the materials in a rotary kiln to liberate carbon dioxide, causing incipient fusion; and fine-grinding of the resultant clinker, with the addition of 4 to 6 percent gypsum. Finished cement is shipped either in bulk or in bags. All portland cement is produced by either a wet or dry grinding process, the distinguishing characteristic being whether the raw materials are introduced into the kiln as a wet slurry or as a dry mixture.

In 1971, 170 plants producing portland cement clinker plus five plants operating grinding mills to produce finished cement were controlled by 51 companies located in 41 states and Puerto Rico. Fifty percent of this cement industry capacity is owned by multiplant companies, and the eight leading companies account for about 47 percent of the total. Overcapacity has resulted in low profit margins, inhibiting modernization and construction of new plants during the past several years, and more stringent air-pollution regulations have increased both capital and operating costs. Recent trends are toward increased operations through installation of larger kilns to replace older marginal kilns, permitting more economic and efficient pollution control. Cement manufacturing plant capacity and size distribution are shown below.

Size Range (metric tons/day)	No. Plants	No. Kilns	Total Annual[1] Capacity (million metric tons)	Total Capacity(%)
Less than 513	6	10	0.8	1.0
514-1025	49	98	12.3	15.8
1026-1538	65	170	27.0	34.6
1539-2051	28	95	16.5	21.1
2052-2564	11	37	8.7	11.2
2565 and up	11	56	12.6	16.3
Totals	170	466	77.9	100.0

[1] Based on 334-day operation.

Size distribution is expected to shift upwards as new plants are constructed and existing plants modified or closed, so the total number of plants is expected to remain about the same. It is also assumed that there will be no major shift in production capacity percentages between dry and wet grinding processes, with the latter presently estimated at 59 percent. Production is typically 75 percent of capacity.

Emission Sources and Pollutants. Primary emission sources are the dry-process blending and grinding, kiln operation, clinker cooler, and finish grinding. Other sources include the feed and materials-handling systems. The primary air pollutant is dust particulates. Estimated dust-emission factor for an uncontrolled dry-process kiln is 180 kg per metric ton of cement, compared with 130 kg per metric ton for the wet-process plant, giving an average emission factor of 151 kg per metric ton of product. The corresponding emission factors for the blending, grinding, and drying processes are 48 and 16 kg per metric ton, respectively, for an average of 29 kg per metric ton.

Control Technology and Costs. Emissions from the blending, grinding, and drying processes are generally controlled with fabric filters. Where ambient gas temperatures are encountered during grinding, conveying, and packaging processes, fabric filters are used almost exclusively. The greatest problems are encountered with high-temperature gas streams which contain appreciable moisture.

Both fabric filters and electrostatic precipitators are used in controlling dust emissions from the kilns. The condensation problems from the high-moisture content in the wet-process plant may be overcome by insulating the ductwork and preheating the systems on start-up. Current state regulations may be met with either fabric filters or electrostatic precipitators; however, new source performance standards will require the filters. At least one plant has a wet scrubber, but its costs were estimated on the basis of an electrostatic precipitator with little error in total estimated costs.

The total cost of control for portland cement plants was found by estimating the costs for control devices for grinding, mixing and drying (drying not included in the wet processes) and kilns, which are the major sources of pollutant. Kilns may have either baghouses for dry-process kilns or electrostatic precipitators for wet-process kilns; baghouses were assumed to have been used in both cases for the combined grinding, mixing, and drying processes. Other sources, including clinker coolers, packaging, and crushing, are not costed due to prevailing industry control prior to the 1970 Clean Air Act and/or minimal costs.

The capital cost of baghouses is assumed to be proportional to the 0.91 power of capacity, while the capital cost of electrostatic precipitators is proportional to the 0.67 power of capacity; in each case, the operating cost is linearly proportional to the capacity. The cost of baghouses for the grinding, mixing, and drying operations was scaled in the same manner. However, the required size was scaled by 0.78 (dry) and 0.26 (wet) to account for the smaller airflow rates of these processes, and the absence of control required for the wet-process raw material grinding mills.

Annualized control costs are detailed in Table 3-30-1.

Table 3-30-1.
Cement Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (1,000 MT/Yr)	154,992	186,080	199,377

Annual Growth Rate Over Period 1976-85 = 3.08%

PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Day)	Pollutants Controlled	Control Technology
Dry Process Kilns	116.7;254.6;437.5; 612.5;770.0;933.3	Particulates	Fabric Filter
Wet Process Kilns	130;254.5;433.3;606.7; 817.1;924.4	Particulates	ESP
Dry Gravel Mix	116.7;254.6;437.5; 612.5;770.0;933.3	Particulates	Fabric Filter
Wet Gravel Mix	130;254.5;433.3;606.7; 817.1;924.4	Particulates	Fabric Filter

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	5,235.45	7,012.04	7,897.26		
Legislated Controls:					
Particulates	2.139.70	19.88	22.42		
CONTROL COSTS (Million 1975 $)					
Investment	289.47	25.08	13.73	990.18	328.94
Total Annual	152.98	244.62	258.26	2,651.60	2,335.92
Capital	80.36	119.49	123.86	1,287.97	1,130.48
O&M	72.62	125.14	134.40	1,363.63	1,205.45

LIME INDUSTRY

Production Characteristics and Capacities. There are currently 186 lime producing plants in the United States. These plants can be divided into four size ranges, based upon output capacity of metric tons per year; the number of plants in each size range and their estimated capacities are shown in Table 3-31-1.

The U.S. lime industry can be conventionally divided into two product sectors. Approximately 35 percent of the output is consumed by the producers, while the remaining 65 percent is sold in the open market. Plants are located in 41 states and Puerto Rico, with over 22 percent of U.S. capacity in Ohio and the other major capacities located in Pennsylvania, Texas, and Michigan; plant size distribution is shown in Table 3-31-1. Recent trends are toward closing of small, old plants and replacing old kilns with larger units.

Table 3-31-1.
Lime Industry Capacity Distributions

Size Range (1,000 metric tons/year)	No. Plants	Estimated 1972 Capacity, (million metric tons/year)	Total Capacity(%)
0-22.7	68	0.6	3.2
22.7-90.9	61	3.0	16.2
90.9-364	52	10.5	56.8
More than 364	5	4.4	23.8
	186	18.5	100.0

In 1972, producers at 186 plants sold or used 18.5 million metric tons. Should the use of lime in processes for the removal of sulfur oxides from combustion gases become standard practice, the demand for lime will be increased substantially. The number of plants, meanwhile, has declined from 195 in 1970 to 186 in 1972. Further consolidation may be expected to economically justify the increased cost of emissions controls.

Lime is formed by expelling carbon dioxide from limestone or dolomitic limestone by high tempertures. This calcination process forms quicklime. Hydrated lime is made by the addition of water to the quicklime. The calcination of dolomite results in dead-burned (refractory) dolomite.

Major uses of lime are for basic oxygen steel furnaces, alkalies, water purification, other chemical processes, and refractory dolomite.

About 73 percent of lime is produced in two basic types of rotary kilns: the long rotary kiln, and the short rotary kiln with external preheater. Vertical kilns are used to supply 27 percent of lime. Almost all new lime production is accomplished using the rotary process.

Emission Sources and Pollutants. Atmospheric emissions from lime manufacture are primarily particulates released when crushing the limestone to kiln size, calcining the limestone in a rotary or vertical kiln, and crushing the lime to size; also, fly ash is released if coal is used in calcination. Other emissions, such as sulfur oxides, may be generated by fuel combustion.

Uncontrolled emissions from rotary kilns are about 100 kg per metric ton of lime processed, compared with 4 kg per metric ton from vertical kilns. However, economics favor use of the rotary kiln, and virtually all new and expanded production is expected to be accomplished by this method.

Control Technology and Costs. Gases leaving a rotary kiln are usually passed through a dust-settling chamber where the coarser material settles out. In many installations, a first-stage, primary dry cyclone collector is used. The removal efficiency at this stage can vary from 25 to 85 percent by weight of the dust being discharged from the kiln.

The selection of a second stage to meet the high efficiency level of 0.03 grains per actual cubic foot may be either a high-energy wet scrubber, fabric filter, or electrostatic precipitator. The higher capital cost of the electrostatic precipitator may be more than offset in specific installations by lower operating and maintenance costs.

It is believed that vertical kilns can be effectively controlled to allowable emission limits with baghouses, scrubbers, or cyclone/scrubber combinations. In the latter cases, efficiencies of 99 percent have been reported.

Capital costs for fabric filters in existing plants were assumed to be twice their cost in new plants. Capital costs for wet scrubbers and electrostatic precipitators in existing plants were assumed to be 50 percent greater than in new plants. Annualized production and cost control data is presented in Table 3-31-2.

Table 3-31-2.
Lime Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985		
Capacity (Million MT/Yr)	21.60	26.74	29.13		
Annual Growth Rate Over the Period 1976-85 = 3.74%					
PROCESS CHARACTERISTICS	Model Plant Size (1,000 MT/Yr)	Pollutants Controlled		Control Technology	
Type 1	10;54;232;686	Particulates		Fabric Filter	
Type 2	10;54;232;686	Particulates		Scrubber	
Type 3	10;54;232;686	Particulates		ESP	
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	1,059.34	1,413.85	1,561.67		
Legislated Controls:					
Particulates	461.53	27.33	29.92		
CONTROL COSTS (Million 1975 $)					
Investment	55.25	3.34	1.80	330.01	110.27
Total Annual	34.93	52.83	54.13	586.42	503.77
Capital	28.89	42.51	43.40	474.83	405.24
O&M	6.04	10.32	10.73	111.59	98.53

STRUCTURAL CLAY PRODUCTS INDUSTRY

Production Characteristics and Capacities. There are currently 466 plants in the United States manufacturing structural clay products, including common brick, fireclay or refractory brick, and sewer pipe. The latter category represents approximately 90 percent of the total production of structural clay materials, with common brick being by far the largest category, or approximately 75 percent of total production. Value of shipments in 1972 were $404 million, $143 million and $13 million for common brick, clay sewer pipe, and fireclay brick, respectively. Plants are located in 45 states with North Carolina, South Carolina, Ohio, Pennsylvania, and Texas accounting for about 45 percent of production capacity.

For purposes of estimating air abatement costs, the industry was divided into those plants using either continuous tunnel kilns or periodic kilns; an average plant capacity was selected for each process, as shown below.

	Av. Cap. (1,000 Mt/Yr)	No. Plants	Est. 1974 Cap. (million Mt/Yr)	Total Cap. (%)
Periodic kilns	21	336	6.9	35
Continuous tunnel kilns	100	130	12.9	65
Totals		466	19.8	100

Miscellaneous clays and shales are used to manufacture common brick, sewer pipe, and refractory brick. Typically, the plants are located in the proximity of the clay mines. The clays are crushed and ground at the plant, after which they are screened and mixed with water for the forming operation. Common brick, sewer pipe and some refractory brick are formed by extrusion; most refractory brick is formed by die pressing.

The formed materials are fire-treated by either continuous tunnel or intermittent periodic kiln processes. In the continuous tunnel kiln, the charge is first preheated by airflow escaping from the bake oven, passed through the oven at temperatures of approximately 1,900°F, and then passed through a cooling stage. In contrast, the periodic kiln heats the charge at ambient temperature to a peak temperature, after which the fuel is shut off, allowing the charge to cool to ambient temperature again; this cycle requires about 2 weeks, during which fuel is burned about 50 percent of the time. The remainder of the period is used for cooling and physical discharging of the product, steps which emit little if any air pollutants.

A process frequently practiced by manufacturers of common brick is flashing. This process involves firing the brick in a reducing atmosphere to achieve architecturally-desirable surface colorations. The process is noted because when it is used in conjunction with periodic kilns, carbon monoxide and/or hydrocarbon emissions usually result.

Emission Sources and Pollutants. Atmospheric emissions from the manufacture of clay construction products are primarily sulfur dioxides released during the firing process, and originating from the sulfur contained in the clay. Uncontrolled sulfur dioxide emissions are estimated to be about 0.37 metric ton per 100 metric tons of clay processed. The flashing process associated with the manufacture of certain types of brick can also result in hydrocarbon and carbon monoxide emissions. Approximately 0.42 metric ton of hydrocarbons and/or carbon monoxide are estimated to be released per 100 metric tons of brick flashed.

Table 3-32-1 summarizes estimated uncontrolled and controlled emissions from the production of clay construction materials.

Control Technology and Costs. It is anticipated that wet scrubbers will be used to control sulfur dioxide emissions from the production of clay contruction materials. Presently, only a few plants were found to be exercising this or any other control option. Control of hydrocarbon and carbon monoxide emissions can be accomplished by the use of afterburners. The requirement for afterburners will depend on the duration of the flashing treatment at different plants. Likewise, it is probable that certain plants will have minimal requirement for scrubbers because of the negligible sulfur content of some clays. About 10 percent of existing plants producing common brick, sewer pipe, and refractory brick were assumed to be either equipped with adequate controls or using new clay materials sufficiently low in sulfur content to avoid the need for wet scrubbers.

Annual costs and industry operating statistics are detailed in Table 3-32-1.

Table 3-32-1.
Structural Clay Products Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (Thousand MT/Day)	135.19	155.73	155.88

Annual Growth Rate Over the Period 1976-85 = 1.07%

PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Day)	Pollutants Controlled	Control Technology
Tunnel Kiln	300	Sulfur Oxides	Wet Scrubber
Periodic Kiln	200	Sulfur Oxides, Hydrocarbons	Wet Scrubber
Periodic Kiln	200	Sulfur Oxides, Hydrocarbons	Thermal Incinerator

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Hydrocarbons	18.55	14.49	9.14		
Sulfur Oxides	80.02	102.59	105.13		
Legislated Controls:					
Hydrocarbons	8.84	0.37	0.23		
Sulfur Oxides	48.77	22.83	23.03		
CONTROL COSTS (Million 1975 $)					
Investment	23.74	0.13	0.68	80.89	17.63
Total Annual	26.38	29.62	25.25	343.14	284.30
Capital	10.30	13.06	13.18	148.65	126.73
O&M	16.08	16.56	12.08	194.49	157.57

SURFACE COATINGS INDUSTRY

Production Characteristics and Capacities. Air emission abatement costs associated with the use of organic-based surface coatings in four industries were considered: automotive, furniture, major appliances, and metal or coil coatings. These industries are considered together because of the general similarities between the coating processes employed, the nature of the resulting emissions, and the abatement technologies deemed applicable.

In 1971, approximately 606 million liters of coatings, i.e., paint, shellac, lacquer, and primers, were consumed by these industries. Since over 75 percent of the coatings used contained about 50 percent organic solvents, significant hydrocarbon emissions resulted during the application and curing stages of the process. Future estimates of the volume of hydrocarbon emissions attributable to surface coating processes must be considered in light of the following factors:

- Increased use of non-hydrocarbon solvent materials, i.e., water-thinnable solutions.
- Application techniques involving solvent-free systems, i.e., powder coatings applied by electrostatic spraying.

Where applicable, these process alternatives would provide as much as a 90 percent reduction in hydrocarbon emissions. Faced with the alternative of conventional emission control techniques (i.e., incineration) industries are expected to adopt the newer coating formulations and application techniques at an accelerated pace. By 1985, as much as 50 percent of the coating processes may employ non-hydrocarbon-based materials.

The coating process consists basically of two steps: application and curing. Both stages produce hydrocarbon emissions through evaporation. The coating is generally applied by a spray gun in a paint spray booth, and the surface is then cured or dried in a drying oven where the solvent is evaporated. A summary of industry production is presented in Table 3-33-1.

Table 3-33-1.
Surface Coatings Industry Distribution (1971)

	No. of Plants	Coating Consumption (million liters)	Percent of Coating Consumption
Automobile	100	246	41
Furniture	7,000[1]	189.5	31
Metal Coil Coating	56	95	16
Major Appliance	144	76	12
Totals		606.5	100

[1] 10 percent of furniture manufacturers account for 65 percent of sales ($).

Automotive Finishing. In 1971, there were 100 motor vehicle (auto, truck, and bus) assembly plants located in 28 states throughout the United States. Included in this group are: motor vehicles and car bodies, truck and bus bodies, motor vehicle parts and accessories, truck trailers, and travel trailers and campers. Approximately 246 million liters of coatings were consumed in finishing operations, which is about 41 percent of the total volume of coatings used by the four industries under consideration.

Furniture Finishing. About 7,000 establishments are engaged in manufacturing the following types of furniture in the United States:

- Wood Household Furniture
- Wood Furniture - Upholstered
- Metal Household Furniture
- Wood Cabinetry
- Household Furniture - Unclassified
- Wood Office Furniture
- Metal Office Furniture
- Public Building Furniture
- Furniture and Fixtures - Unclassified.

Approximately 10 percent of the establishments account for 65 percent of industry sales, with the 10 largest producers representing nearly 20 percent of industry sales. Furniture is manufactured in all but seven states, and North Carolina, the principal producer, accounts for 22 percent of the total shipment value.

About 190 million liters of organic solvent-based coatings were consumed by the industry in 1971. Between 1967 and 1972, paint consumption has grown about 5 percent annually. Unlike the metal surfaces coatings, the use of water-based paints and finishes for wood furniture is limited in practice because of the tendency for the occurrence of surface distortions in the wood. Virtually all coatings used, therefore, are hydrocarbon-based and range from 30 to 70 percent by weight in organic content.

Coil Coating. The coil coating process consists primarily of the pretreatment of sheet metal in the strip or coil form, followed by the application of an organic coating and subsequent curing (or baking) to obtain the desired surface characteristics. It is estimated that 56 plants in the United States are engaged in this coating process. Almost 60 percent of the plants are located in Pennsylvania, Ohio, and Illinois, presumably near sources of steel production. In 1971, approximately 95 million liters of coatings were consumed by coil coating processes, representing an annual increase of 14 percent since 1964 when about 38 million liters were consumed.

Major Appliances. In 1971, there were 144 plants in the United States engaged in the production of major appliances including: cooking equipment, refrigerators and freezers, and laundry equipment; about 76 million liters of coatings were consumed in this production effort. Growth in industry consumption of coatings averaged 4 percent annually between 1964 and 1971.

Emissions and Sources of Pollutants. While paint spray booths are a source of hydrocarbon emission, the volume of solvent released to the air through evaporation is dependent on the degree of overspray, which can vary anywhere from 10 to 90 percent. Aerosols resulting from overspray are usually removed by filters or water scrubbers, but these devices have little impact on removal of emissions due to solvent evaporation. The major source of emissions attributable to coating processes are the drying ovens.

Control Technology and Costs. Incineration of the solvent vapors in the exhaust gases from the spray booths and the drying ovens is presently the most practicable technique for limiting hydrocarbon emissions from surface coating operations. Control costs are primarily a function of the exhaust gas volume.

Incineration essentially involves oxidation of hydrocarbons in the exhaust gases to form carbon dioxide and water. Several alternative techniques are available, including flame combustion, thermal combustion, and catalytic combustion. Presently, technical considerations favor the use of thermal incinerators. However, as continuing fuel shortages prevail and prices rise, catalytic units will probably become more economical in the future. To offset the impact of current fuel shortages, thermal incinerators with heat exchange units were considered to be most applicable for all but the furniture category where little curing is employed. The heat exchanger extracts waste heat from the hot exhaust gases, enabling reuse and operating economy.

A summary of estimated investment and annual operating costs per model plant are provided in Table 3-33-2.

Table 3-33-2.
Surface Coating Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (Million Liters/Day)	1.32	2.17	2.42

Annual Growth Rate Over the Period 1976-85 = 6.38%

PROCESS CHARACTERISTICS	Model Plant Sizes (Liters/Day)	Pollutants Controlled	Control Technology
Application and Curing	2,274;9,854; 175,477	Hydrocarbons	Vapor Incineration

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
Hydrocarbons					
1971 Controls:					
Auto	147.19	212.09	246.04		
Major Appliance	49.53	82.93	103.78		
Furniture	148.09	243.73	273.00		
Metal Coil	60.09	81.34	90.83		
Legislated Controls:					
Auto	130.06	177.23	9.26		
Major Appliance	43.98	66.52	3.87		
Furniture	67.69	23.37	26.33		
Metal Coil	58.75	68.42	3.43		
CONTROL COSTS (Million 1975 $)					
Investment	9.58	8.57	5.48	514.46	217.72
Total Annual	193.37	385.65	425.76	4,098.47	3,633.06
Capital	48.30	78.85	83.71	870.16	742.17
O&M	145.07	306.81	342.03	3,228.31	2,890.89

STEAM ELECTRIC POWER PLANTS

Operating Characteristics. Among the largest stationary sources of air pollution are the coal, oil, and natural gas burners. Of the three fuels, coal is the most polluting and natural gas is the cleanest and most convenient to use. The principal uses for these fuels include furnace operation in steam electric power plants, steam generation and heating in the industrial sector, and space heating in the commercial and residential sectors. In 1976, 87 percent of the steam coal (in contrast to coking coal) produced was used for power generation. About 63 percent of all residual fuel oil consumed and 18 percent of natural gas produced was used for the same purpose. It is apparent from these estimates that utility power burners are the major sources of emission for the pollutants of concern, because they burn the most polluting fuels in the largest quantities.

Emission Sources and Pollutants. In the near future, energy resources that will be consumed in large amounts are the nuclear fuels with their radioactive-waste-disposal requirements, and the fossil fuels with their residue disposal and gaseous emission-control requirements. Among the fossil fuels, natural gas is the cleanest, but it is in short supply. To demonstrate the cleanliness of gas relative to coal and oil, the emissions resulting from the use of each fuel in a typical uncontrolled 1,000 megawatt power plant are given below.

Emissions (kilograms per hour)

Fuel	Particulates	SO_2	NO_x
Coal	69,000	41,000	13,000
Oil	600	12,500	8,600
Gas	170	7	6,800

Natural gas is the preferred fuel from an emissions standpoint. Gas-fired power plants provided 16 percent of electricity produced in 1975, and gas provided about one-fifth of all the heating energy derived from fossil fuels. The production of gas in the near future is expected to remain fairly constant, and the growing fossil fuel demand will be supplied by coal and oil.

Despite current shortages in the United States, petroleum is still an abundant fuel internationally. For mobile sources, its derivatives, gasoline and diesel oil, are not expected to be supplanted in the near future. For utility power burners, despite the potential switch from oil to coal in many power plants, distillate and residual fuel oil will continue to supply a significant fraction of the energy required in 1980. Fuel oils for utility burners contain sulfur (typical sulfur contents average about 0.7 percent for United States crude oils and about 2.2 percent for imported crude oils), much of which is removed from the final product. The ash from residual oil combustion is low, about 0.5 percent.

The supply of crude oil and its derivatives in the United States is becoming increasingly critical as a result of limited reserves of domestic sources and increasing international demand for this versatile fuel. Furthermore, oil is in greater demand for producing electrical power in areas where foreign oil was, and probably will continue to be, more accessible.

The most abundant fossil fuel in this country is coal. In 1975, about 405 million tons of coal were burned to produce about half of the electrical power. In 1975, 70 million tons were used for heating, 83 million tons were used to produce coke for use in industrial processes, and 64 million tons were exported. The resources of coal are widespread throughout the United States, but coal has not been used in proportion to its availability in comparison with the other fuels.

Coal typically has an ash content of 9 percent, of which (under uncontrolled conditions) about 85 percent would be emitted from a dry-bottom boiler, and 65 percent from a wet-botton boiler. The resulting emissions would be orders of magnitude higher than those from the other fossil fuels. Particulate controls of varying efficiencies are found on all but the smallest coal burners.

Sulfur dioxide emissions from coal burning are even more serious and more difficult to control. In 1975, the sulfur content of coal burned by utilities, averaged 2.2 percent; this sulfur appears as sulfur dioxide and some sulfur trioxide. To reduce the sulfur oxides, a coal of low-sulfur content could be chosen. However, much of the Eastern low-sulfur coal is reserved for use as coke by the metals industries. In only a small percentage of current coal production is the sulfur content low enough to meet New Source Performance Standards. The major Western low-sulfur coals will be used primarily in the West and Central Regions.

Use of coal to supply most electric power in the near future seems unavoidable. Therefore, more stringent emission controls will be needed. In addition to switching to low-sulfur coal, other strategies are possible, such as removal of sulfur from flue gases, and removal of sulfur from high sulfur fuels before burning.

The uncontrolled and controlled emissions from utility fossil-fuel burners may be estimated from known (measured) emission factors, for the first case, and from the capability of the various control techniques in the second.

Control Technologies and Costs. The following paragraphs analyze the different technologies presently employed to control sulfur oxides, nitrogen oxides, particulates, and the related costs.

Sulfur Oxides. The state-of-the-art of flue gas desulfurization (FGD) is such that the so-called throwaway scrubbing systems (lime and limestone) will predominate through 1980. By 1980, roughly 45 percent of all capacity with sulfur oxide controls will be using limestone scrubbing, while 30 percent will use lime scrubbing. The balance (about 25 percent) will be divided equally between lime/limestone and "other" control methods, including the use of regenerative systems. On this basis, the capital and operating costs used for FGD through 1980 will be the weighted average of lime and limestone costs. The capital, operating, and annual costs of FGD systems are as follows:

	New Plants	Existing Plants
Investment ($/kw)	51	72
O&M (mills/kw hr)	1.2	2.0
Annual (mills/kw hr)	3.0	4.0

For these plants, it was assumed that the cumulative generating capacity controlled by this technique in 1971, 1972, 1975, and 1980 will be 0, 1,000, 7,000, and 33,000 megawatts, respectively. Recent estimates show a more accelerated application of flue gas desulfurization technology. (See EPA Draft Report, "The Economic Impact of EPA's Air and Water Regulations on the Electric Utility Industry", November 1975.) Investment costs for each period were simply computed by multiplying the dollars per kilowatt by the net generating capacity for which FGD systems were installed in that period.

Operating and maintenance costs (and in general time-dependent costs) for a given period were computed using an operating rate of 55 percent and the cost in mils per kilowatt hour. The time, in years, that a certain annual increment controlled generating capacity contributes to the time period under consideration as well as the magnitude of the increment will determine its contribution to the total cost in that period. The sum of the products of incremental megawatt capacity and number of years contributed was used to compute the O&M as well as annual and depreciation (10-year) costs.

The same procedure was used to compute the costs of FGD for existing plants. An operating rate of 70 percent was assumed for these plants.

It is projected that a significant number of Central and Eastern utilities, usually burning high-sulfur coal, will switch to burning Western and much less significantly, Eastern low-sulfur coal. It is estimated that cumulative generating capacities of 880 trillion, 1,540 trillion and 1,650 trillion Btu's per year will switch from high-to low-sulfur coal in 1975, 1977, and 1980, respectively. Western low-sulfur coal will be transported over long distances, and this will double or triple the cost of the coal. Some modifications in converting the power plant to low-sulfur coal are necessary; these changes are related to such items as increased capacity of coal pulverization equipment necessary to handle the higher tonnages and derating of the power plant owing to the lower heating value of Western low-sulfur coals.

In the period 1975-80, two other sulfur oxide methods of abatement will be employed in coal burners. These will involve the increased use of physically-cleaned coal and the blending of low-sulfur coal with high-sulfur coal. In some instances, low-sulfur coal will be burned exclusively during episodes of adverse meteorological conditions.

The approach used here was to use FEA's base case scenario for the total utilization of oil and gas. Thus, the projected energy scenario outlined in Table 3-34-1, with a modification to represent the expected switch of some existing oil burning plants back to coal:

Table 3-34-1.
Energy Consumption by Oil and Gas Burners

(In Trillion Btu/Year)

Fuel	1970	1975		1980	
Distillate Oil (0.3%S)	140	240	482	389	706
Fuel Oil (1%S)	1,100	1,942	2,471	3,137	4,067
Fuel Oil (1-2%S)	390	682	412	1,098	676
Fuel Oil (2+%S)	450	785	285	1,304	470
Natural Gas	4,000	3,274	3,274	2,948	2,948
Coal Switch	0	113	113	985	985

The differential fuel costs resulting from the utilization of Western and Eastern low-sulfur coal are given below.

	¢/Million Btu	
	Western, Chicago	Eastern, Cleveland
Cost of high sulfur coal	47	37
Cost of low-sulfur coal as burned	60	73
Cost of boiler modifications (as explained above)	3	3
Differential fuel cost due to CAA	16	39

It is not known at this time what percentage of the low-sulfur coal usage will be Western and what the price will be to burn it. However, most of the coal usage will be Western, and the differential price of 16 cents per trillion Btu will be used as explained above. The unit costs of physically cleaning and blending coal (transportation and storage mainly) are $4.5 and $0.25 per ton, respectively.

Fuel oil burning utilities will in some cases be required to switch to low-sulfur fuel oil. The costs of the various grades with respect to sulfur content are given below.

	% Sulfur	¢ per Million Btu
Distillate	0.3	90
Fuel Oil	1.0	82
Fuel Oil	1-2	71
Fuel Oil	2	65

For the conversion of Eastern utilities to low-sulfur coal, only quantities involved between 1975 and 1980 were considered. Taking 1975 as the baseline year (zero conversion) the post-1975 conversion data was used. The levels are 40 million and 77 million tons per year in the periods 1976-77 and 1978-80, respectively. In the period 1975 to 1980, this will amount to a total of 272 million tons. The cost at 16 cents per million Btu will come to a total of $800 million in the period under consideration.

Physical coal cleaning and blending in the period 1975 to 1980 will involve 65 and 182.5 million tons in the respective categories. The respective costs will be $292 million and $46 million.

In oil-burning utilities, the differential fuel costs resulting from switching to low-sulfur fuel oils and distillates has been estimated by integrating the differentials between the baseline case and that projected for the years 1975 through 1980 in Table 3-34-1.

Nitrogen Oxides. These pollutants will be controlled by applying staged combustion and off-stoichiometric firing. The unit costs for a 500 megawatt plant burning coal, oil, and gas were used in assessing the total cost of control. It was assumed that emissions of nitrogen oxides will be abated by the above technique starting in July 1975. While it is recognized that this may not necessarily take place, the costs obtained by this assumption will represent an upper limit for the period 1975-80. Variances and exemptions issued in Air Quality Control Regions (AQCR) where the ambient levels of this pollutant are not critical will of course lower the overall costs of control.

The above-mentioned control technique applies only to dry bottom boilers; wet bottom boilers are not amenable to this abatement technique. Consequently, if total control is desired, massive conversion of the estimated 17 percent of the coal steam-electric generating capacity with wet bottom boilers will have to be converted to the dry bottom type.

Berkau's unit cost data were used, wherein a 500 megawatt model plant was assumed; the investment costs were as follows:

Fuel	$ per kw	
	New	Existing*
Oil/Gas	0.56	0.75
Coal	2.75	3.04

*Costs for new plants multiplied by a retrofit difficulty factor of 1.35. Operation and maintenance and total annual costs were assumed to be 2 and 18 percent of investment per year; depreciation was assumed to be 14 percent per year.

It appears that only AQCR's 24 and 67, whose boundaries encompass the cities of Los Angeles and Chicago, respectively, will restrict nitrogen oxide emissions from utility burners. In Los Angeles, the 1975 total oil and gas fired capacity to be controlled amounts to 11,770 megawatts of coal, oil, and gas burning facilities. An additional 2,000 megawatts of coal burning capacity is estimated to be on-stream by 1978. Estimates of control costs in these two AQCR's were made and added to the national estimates.

Control of Particulates in Coal Burners. It is estimated that about 75 percent of all coal-burning power plants existing in 1970 had particulate removal equipment of about 90 percent efficiency. However, it should be noted at this point that it is difficult to substantiate this because of a lack of data. Stringent local (city and state) regulations initiated the expansion of serious efforts to control particulates in the late 1960's and early 1970's. The assumption has been made that a gradual upgrading of particulate control devices to 99.9 percent efficiency or better will take place.

All generating capacity in operation before 1975 is considered to be controlled by electrostatic precipitators, and existing capacity for which FGD systems will be installed before and after 1975 will not require additional particulate control capability. New generating capacity coming into operation after 1975 and for which FGD will be applied will require a particulate control level up to 95 percent using electrostatic precipitators; this is roughly half the investment required for control up to 99.5 percent.

Generating capacity existing in 1971 together with that coming on line between 1971 and 1975 (after FGD capacity is subtracted) will have capacity efficiency upgraded to 99.9 percent by electrostatic precipitators. Increments to the 1975 capacity (after taking out all FGD) will be controlled to 99.9 percent efficiency by electrostatic precipitators and wet venturi scrubbing; the breakdown will be 90 and 10 percent, respectively. The breakdown in capacity to be controlled as explained above is shown in Table 3-34-2.

Table 3-34-2.
Control of Particulates 1971 to 1980
(Trillion Btu Coal Burning Capacity)

Year	FGD[1] Existing	FGD[2] New	Remaining Capacity[3] 99.9 Percent ESP	Remaining Capacity[3] 99.9 Percent Venturi Scrubbing
1971	0	0	7,800[4]	0
1972	48.2	0	8,350	0
1973	79.5	0	9,000	0
1974	154	0	9,700	0
1975	337	0	10,500	0
1976	761	221	10,680	20
1977	1,340	552	10,760	10
1978	1,410	748	11,460	100
1979	1,490	1,060	12,080	100
1980	1,590	1,410	12,670	100

[1] No particulate controls necessary. Variances granted up to time of installation of FGD.

[2] Control to 95 percent before FGD system.

[3] Calculated by difference assuming on operating rate of 55 and 70 percent of existing and new plants with FGD installed. A heat rate of 0.01 trillion Btu per kw hr was also assumed.

[4] 1971 capacity will require only half the investment in upgrading from 95 to 99.9 percent.

Unit Costs of Particulate Control. The following costs were used for 99.5 percent particulate control units:

	ESP	Venturi Scrubbing
Investment ($ per kw)	20.0*	30.0*
O&M ($ per kw-yr)	0.35	2.6

* Applying applicable inflation factors result in investments of 43 and 46 in 1975$ for ESP and Venturi Scrubbing, respectively.

Capacity existing in 1971 will be gradually (1971 to 1975) upgraded from 90 to 99.9 percent. This implies that half the investment will be required and time-dependent charges (O&M and annual) will carry for only 2 years instead of 4 years.

The most recent anlaysis of costs for this sector was provided to the Agency by Temple, Barker & Sloane, Inc. (TBS)[1]. This analysis was conducted in somewhat greater depth than, and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure, and is considered to be more precise. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The TBS estimates are as follows (in million 1975 dollars):

Incremental Investment	(1975-1985)	20,000
O&M in 1985		2,700

The TBS study results are listed below (in billion 1975 dollars):

	1975-1980	1975-1985
Flue Gas Desulfurization	9.3	12.8
Eastern Medium Sulfur Coal	0.9	0.9
Western Low Sulfur Coal		
Equipment Modifications	0.6	1.3
Precipitators	2.0	4.2
Washing and Blending	0.2	0.2
Other Precipitators	0.6	0.6
TOTAL	13.6	20.0

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with

SEAS lists 5.8 billion associated with flue gas desulfurization in 1975-1985, and 4.5 billion during the period 1975-1980. As can be noted, this is approximately half of the later, revised TBS calculations. The forecasts for electrostatic precipitators capital expenditures in SEAS are 3.0 billion for 1975-1985 and 2.5 billion for 1975-1980. SEAS assumed all costs associated with fuel-switching were O&M, as opposed to capital investment required by the standard regulations. Much of the difference between the two studies is due to assumptions about capacity covered by the regulations and interpretation of costs associated with the implementation of the standards.

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[1] "The Economic Impact of EPA's Air and WAter Regulations on the Electric Utilities Industries", Temple, Barker & Sloane, Inc., November, 1975.

Table 3-34-3.
Steam-Electric Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (Mega Megawatts)	0.73	1.12	1.26

Annual Growth Rate Over the Period 1976-85 = 11.89%

PROCESS CHARACTERISTICS	Pollutants Controlled	Control Technology
Coal	Particulates	Venturi Scrubbers;ESP
	Nitrogen Oxides	Burner Modification
	Sulfur Oxides	Flue Gas Desulfurization
	Hydrocarbons	None Applicable
	Carbon Monoxide	None Applicable
	Other Gases & Mists	None Applicable
Oil	Particulates	None Applicable
	Nitrogen Oxides	Burner Modification
	Hydrocarbons	None Applicable
	Carbon Monoxide	None Applicable
	Sulfur Oxide	None Applicable

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:	29,446.74	38,565.97	41,544.68		
Particulates	4,542.52	6,144.04	6,673.94		
Nitrogen Oxides	6,024.67	7,963.90	8,905.93		
Sulfur Oxides	18,551.79	24,018.66	25,474.75		
Hydrocarbons	79.46	110.92	126.62		
Carbon Monoxide	248.08	328.15	363.11		
Other Gases & Mists	0.22	0.30	0.33		

Table 3-34-3.
Steam-Electric Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985		
Legislated Controls:	19,819.85	16,415.40	19,147.81		
Particulates	2,140.07	509.91	579.41		
Nitrogen Oxides	6,244.42	8,315.29	9,992.42		
Sulfur Oxides	11,415.50	7,030.79	7,994.84		
Hydrocarbons	83.62	123.81	143.92		
Carbon Monoxide	261.56	356.93	424.16		
Other Gases & Mists	0.23	0.32	0.35		
CONTROL COSTS (Million 1975 $)					
Investment	960.38	645.89	187.68	10,353.11	7,905.69
Total Annual	977.00	2,691.36	2,702.66	26,630.16	24,537.80
Capital	322.50	1,121.02	1,361.90	11,384.22	10,730.12
O&M	654.50	1,570.34	1,340.76	15,245.93	13,807.68

SOLID WASTE DISPOSAL

Solid waste disposal contributes to air pollution from incineration and open burning methods. Air pollutants emitted to the atmosphere from such practices include particulates, carbon monoxide, sulfur oxides, nitrogen oxides, fluorocarbons, hydrochoric acid, and odors. The levels of pollutants emitted are primarily dependent on the input or the material being burned; incinerator levels are also dependent on the specific incinerator design and upon the specific methods of operation. Particulate emissions are the highest concentrations, making them the specific pollutant subject to controls. There are no current Federal regulations for odors, hydrochloric acid, and fluorocarbons.

The solid waste disposal methods that are discussed in the following paragraphs were in use in 1971 in the proportions shown below:

Disposal Method	Solid Waste Disposed (%)
Municipal Incinerators	5.3
On-Site Incinerators (Commercial and Industrial)	8.3
Open Burning and Open Dumps	22.2
Other Methods	64.2
Total Disposed Wastes	100.0

MUNICIPAL INCINERATORS

Operating Characteristics and Capacities. Basically, there are two types of municipal incinerators: the refractory-lined furnace type, the most common in this country, and the water-wall or waste-heat recovery type, more common in Europe. The water-wall units offer the advantage of steam generation, and as a consequence of heat recovered during steam generation, flue-gas temperatures are lower than the refractory-lined units. Incinerators with lower gas temperatures have smaller volumes of flue gases to control, and thus require smaller, less-costly air-pollution control equipment. In addition, with the low temperatures from heat recovery, incinerators can utilize control equipment that could not survive the higher temperature flue gases from the refractory-lined furnaces.

Emission Sources and Pollutants. Municipal incinerators contribute to air pollution by releasing a variety of pollutants to the atmosphere that include particulates, hydrocarbons, sulfur oxides, fluorocarbons, nitrogen oxides and carbon monoxides. The levels of these pollutant emissions are directly related to the design and operation of the incinerator, but more importantly to the input charge. Of these pollutants, normally only the particulates are considered to be emitted in concentrations that are high enough to warrant controls.

Control Technology and Costs. Both high-efficiency wet scrubbers and electrostatic precipitators are capable of collection efficiencies to meet emission regulations of 91 grams per 45.4 kilograms of refuse charged. Annualized control costs and industry statistics are detailed in Table 3-35-1.

ON-SITE INCINERATORS (COMMERCIAL AND INDUSTRIAL)

Operating Characteristics and Capabilities. In 1972, there were approximately 100,000 on-site incinerators in use in this country. These intermediate-sized units are usually associated with office buildings, large retail stores and apartment buildings. Of the over 23 million metric tons of solid waste incinerated annually in the United States, more than one-third is processed by on-site units that typically process about 90 tons annually, or approximately 104 kilograms per hour. States bordering the Great Lakes (Minnesota, Ohio, Illinois, Wisconsin, Michigan, Indiana, New York, and Pennsylvania) account for about 60 percent of the total number of on-site units in the United States.

There are two types of commercial building and industrial incinerators: single-chamber and multiple-chamber. Single-chamber incinerators are similar to residential or domestic units and consist of a refractory-lined chamber with a grate on which the refuse is burned. Combustion products are formed by contact between under-fire air and waste on the grate. Additional air (over-fire air) is admitted above the burning waste to promote complete combustion. Multiple-chamber incinerators employ a second chamber to which combustion gases from the primary chamber are directed for further oxidation of combustible gases. Auxiliary burners are sometimes employed in the second chamber to increase the combustion temperature.

It is estimated that the use of apartment incinerators, which account for about 6 percent of installations for refuse disposal, will become virtually extinct during the

1976-85 period. The number of industrial and commercial units should remain stable during that decade because new installations will primarily be replacements of older units.

Approximatly 88 percent of all on-site incinerators are the multiple-chamber type; emissions from multiple-chamber incinerators are generally lower than the single-chamber incinerators. The design capacity of the incinerator in this report is from 23 kilograms per hour to 1,816 kilograms per hour, and the average incinerator operates between 3-5 hours a day.

Emission Sources and Pollutants. While on-site units emit various products of combustion, only particulates (fly ash) are released in sufficient quantities to warrant installation of controls. Approximate emission factors for single-chamber and multiple-chamber incinerators of intermediate size are respectively 7.5 and 3.5 kilograms per metric ton of refuse charged.

Control Technology and Costs. Operating conditions (e.g., air supply to the combustion chamber), refuse composition, and basic incinerator design have a pronounced effect on the volume and composition of air emissions. Afterburners and wet scrubbers can be installed to control particulate emissions and some other combustion products. However, with the shortage of natural gas and the expense of fuel oil, the use of afterburners as retrofit controls on building incinerators will probably be curtailed. Furthermore, the newer multiple-chamber units already employ auxiliary firing techniques which in effect fulfills the function of an afterburner.

Wet scrubbers will achieve an approximate 80 percent reduction in particulates emissions. This level of control is sufficient to meet Federal particulate emission standards of 2 kilograms per metric ton of refuse charged.

Annualized control costs and performance statistics are detailed in Table 3-35-1.

OPEN BURNING AND OPEN DUMPS

Emission Sources and Pollutants. Open burning refers to the indiscriminate and unconfined burning of wastes, such as leaves, landscape refuse, and other rubbish. Open dump burning refers to unconfined burning of refuse at municipal dumps. Emissions from open dumps reflect the composition of the refuse as well as the volume of such items as paper, plastics, garbage, etc. The primary emissions from open burning are particulates, smoke, and products of combustion.

Control Technology and Costs. There is no control technology that can be applied to open burning, and the only suitable alternatives for emissions control are the use of municipal incinerators for disposal and the use of sanitary landfills. It was assumed that all on-site open burning and the resultant wastes would be diverted to sanitary landfills. Annualized costs and process characteristics are detailed in Table 3-35-1.

Table 3-35-1.
Solid Waste Disposal Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity			
Municipal Incin. (MT/Day)	44.49	52.00	51.89
Open Burning (MT/Day)	159.30	206.62	217.34
On-Site Incin. (MT/Yr)	793.86	856.57	787.44

Annual Growth Rate Over the Period 1976-85:

Municipal Incineration = 2.16%
Open Burning = 3.66%
On-Site Incineration = 0.52%

PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Day)	Pollutants Controlled	Control Technology
Municipal Incinerators	300	Particulates	ESP and Wet Scrubber
Open Burning	100,300,500,700, 900,1500	Particulates	Landfill (Close or Remote)
On-Site Incineration	100,300,500,700, 900,1500	Particulates	Landfill (Close) or Wet Scrubber

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	148.78	183.52	183.44		
Legislated Controls:					
Particulates	88.43	58.06	57.60		

Table 3-35-1. (Continued)
Solid Waste Disposal Industry Data Summary

CONTROL COSTS (Million 1975 $)	1975	1980	1985	1971-85	1976-85
Investment	133.09	42.72	3.29	1,948.33	634.68
Municipal Incinerators	0	3.98	0	162.24	93.65
Open Burning	57.43	28.85	3.29	1,288.66	233.60
On-Site Incineration	75.66	9.89	0	497.43	307.43
Total Annual	446.16	721.01	733.15	7,705.35	6,700.41
Capital	189.09	274.70	279.18	3,046.92	2,602.15
Municipal Incinerators	9.36	21.77	22.13	223.63	198.21
Open Burning	123.93	147.71	151.35	1,757.43	1,430.59
On-Site Incineration	55.70	105.22	105.70	1,065.86	973.35
O&M	257.07	446.31	453.97	4,658.43	4,098.26
Municipal Incinerators	24.88	41.40	41.31	458.11	397.39
Open Burning	171.24	302.57	318.57	3,125.32	2,763.58
On-Site Incineration	60.95	102.34	94.09	1,075.00	937.29

SEWAGE SLUDGE INCINERATION INDUSTRY

Operating Characteristics and Capacities. Incineration is one of several methods currently practiced for the disposal of sludges accumulated by the municipal sewage treatment plants. There are four types of sewage sludge incinerators:

- Multiple-hearth
- Fluidized bed
- Flash drying
- Cyclonic-type.

The majority of existing installations are the multiple-hearth type. The capacity distribution of sewage sludge incinerators in 1968 is shown below:

Number of Installations	Capacity Range, Metric TPD[1] (dry solids)	Capacity Metric TPD (dry solids)	Total Capacity(%)	Average Cap. Metric TPD(dry solids)
51	0.27- 9.1	270	27.13	5.3
103	9.2 - 45.3	2,132	54.79	20.7
27	45.4 - 90.7	1,705	14.36	63.4
7	90.8 -272.0	1,214	3.72	173.4
188		5,321	100.00	

[1] TPD is the abbreviation for tons per day.

Emission Sources and Pollutants. Particulate emissions from uncontrolled sewage-sludge incinerators range from 32 grains per DSCM (dry standard cubic meter) for multiple-hearth type, and 282 gr per DSCM for fluidized-bed type incinerators. Particulate emissions from existing facilities controlled by wet scrubbers range from 0.35 to 2.12 gr per DSCM, with an average value of 1.45 gr per DSCM. New source performance standards proposed by EPA limit the particulate emissions at no more than 1.09 gr per DSCM.

Control Technology and Costs. All sewage sludge incinerators in the United States are equipped with wet scrubbers that have varying collection efficiency. The scrubbers range from low-energy types, with pressure drops in the range of

2.5 to 6 inches of water, to high-energy scrubbers with a pressure drop of 18 inches of water.

Control estimates of particulate emissions from sewage sludge incinerators were based on the following assumptions:

1. Incinerator operating schedules are 3,640 hours per year for installations with capacities in the range of 0.3 to 45 metric tons per day, and 8,736 hours per year for installations with capacities in the range of 45.1 to 272 metric tons per day.

2. The majority of the existing installations are controlling particulate emissions to about 90 percent, or 1.5 kg per metric ton.

3. To meet State Implementation Plans, existing facilities were to be upgraded by 1975 to control particulate emissions to no more than 2 kg per metric ton. New facilities will be controlled to an emission level of no more than 0.8 kg per metric ton.

Table 3-36-1 details the investment, annual costs, and total cash requirements for the industry along with operating statistics.

Table 3-36-1.
Sewage Sludge Incineration Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985		
Capacity (MT/Day)	14,260	25,293	33,899		
Annual Growth Rate Over the Period 1976-85 = 8.16%					
PROCESS CHARACTERISTICS	Model Plant Sizes (MT/Day)	Pollutants Controlled		Control Technology	
Incineration	5.28;21;63;178	Particulates		Wet Scrubbers	
EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	38.58	68.94	92.36		
Legislated Controls:					
Particulates	19.58	11.27	10.78		
CONTROL COSTS (Million 1975 $)[1]					
Investment	13.22	6.10	5.93	186.30	111.40
Total Annual	15.74	36.05	44.02	382.02	346.16
Capital	10.09	21.54	24.68	228.60	204.30
O&M	5.65	14.51	19.34	153.42	141.86

[1] These costs are not included in the municipal water pollution control cost estimates in Section Three.

GRAIN HANDLING INDUSTRY

Production Characteristics and Capacities. Traditionally, grain handling is considered in terms of series of grain storage facilities starting from the delivery by the farmer and ending with the ultimate user. These grain storage facilities or grain elevators, provide storage space and serve as collection, transfer, drying, and cleaning points. There are two main classifications of grain elevators--country and terminal elevators. Country elevators receive grains from nearby farms by truck for storage or shipment to terminal elevators or processors. Terminal elevators (this category is subdivided into inland and port terminals), are generally larger than country elevators and are located at significant transportation or trade centers. Inland terminals receive, store, handle, and load these grains in rail cars or barges for shipment to processors or port locations. Port terminals receive grain and load ships for export to foreign countries. It has been noted that particulate emission is a function of both the amount of grain handled and the operations involved in handling. The cost of equipment for emission control is a function of the size of the facility and operations involved. Consequently, model sizes for the types of operations and size of country elevators, inland terminals and port terminals have been selected, ranging from 0 to 70 thousand kiloliters (dry measure), 70 to 700 thousand kiloliters, and 0.7 to 7 million kiloliters. It should be noted that very few country elevators fall within the second range, while some inland terminal elevators may fall within the first capacity range.

Using data for the number and storage capacities of the country and terminal elevators by states as of September 30, 1972, size ranges and number of facilities per size range are estimated in Table 3-37-1.

Table 3-37-1.
Grain Handling Industry
Facilities Production Capacities

Ranges (thousand kl/yr)	Total Volume Handled (million kl/yr)	Total Volume(%)	No. of Facilities	Average Volume (thousand kl/yr)
0-70	217	55.5	7,147	30.4
70-700	70.9	18.1	413	171.6
700-7,000	103	26.4	64	1,615
Totals	390.9	100.0	7,624	

Emission Sources and Pollutants. Grain handling includes a variety of operations which emit differing amounts of air pollutants, primarily particulates. The particulates consist of attrition of the grain kernels and dirt. Hence, the amount of the dust (particulates) emitted during the various grain handling operations depends on the type of grain being handled, the quality or grade of the grain, the moisture content of the grain, the speed of the belt conveyors used to transport the grain, and the extent and the efficiency of dust-collecting system being used, such as hoods and sheds.

Control Technology and Costs. Systems used to control particulate emissions from grain handling operations consist of either extensive hooding and aspiration systems leading to a dust collector or methods for eliminating emissions at the source. Techniques which eliminate the sources of dust emissions or which retain it in the process are enclosed conveyors, covers on bins, tanks and hoppers, and maintenance of the system's internal pressure below the external pressure so that airflow is directed in rather than out of the openings.

Control methods are also available to capture and collect the dust entrained or suspended in the air. The dust collection systems generally used are cyclones and fabric filters.

In order to meet the emission standards, it is assumed that (except for grain drying) fabric filters will be installed in all existing plants that do not have them or as replacements for cyclones and other control devices.

Table 3-37-2 shows the future estimated sales of grains and the volume of grain handled by the two types of elevators.

Table 3-37-2.
Grain Handling Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (10^9 Liters/Yr)	497.13	562.73	641.79

Annual Growth Rate Over the Period 1976-85 = 2.82%

PROCESS CHARACTERISTICS	Model Facility Size (10^9 Liters/Yr)	Pollutants Controlled	Control Technology
Grain Elevator	35;210;1,750	Particulates	Baghouse

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Particulates	1,024.48	1,192.54	1,353.32		
Legislated Controls:					
Particulates	423.55	24.53	27.89		
CONTROL COSTS (Million 1975 $)					
Investment	701.06	87.08	51.40	2,978.52	1,205.35
Total Annual	187.42	329.79	362.89	3,666.63	3,316.75
Capital	167.39	292.09	326.04	3,269.14	2,962.16
O&M	20.03	37.70	36.85	397.49	354.58

DRY CLEANING INDUSTRY

Production Characteristics and Capacities. There are basically two types of dry cleaning installations; those using synthetic solvents, such as perchlorethylene, and those using petroleum solvents, such as Stoddard. The trend in dry cleaning operations today is toward smaller-packaged installations located in shopping centers and surburban districts. These installations use synthetic solvents while the older, larger commercial plants still use the petroleum solvents. It is estimated that approximately 55 percent of dry-cleaning is accomplished by synthetic solvents, with the remaining 45 percent accomplished by petroleum solvents. Now that the small, older petroleum solvent plant is being replaced by synthetic plants, it is estimated that 80 percent of the dry-cleaning in 1980 will be accomplished using synthetic solvents. The larger, commercial plants using petroleum solvents will comprise only 20 percent of the market.

Emissions Sources and Pollutants. Older synthetic solvent plants, which are using separate vessels for cleaning and drying, emit about 105 kg of hydrocarbons per metric ton of textiles. The modern synthetic solvent plants combine the cleaning and drying operation utilizing one vessel, a tumbler that is equipped with a condenser for vapor solvent recovery. Emissions from the single-vessel unit average about 47 kg per metric ton of textiles. Plants utilizing activated-carbon absorption systems for further vapor recovery can reduce the emissions to 38 kg per metric ton for the older plants, and about 25 kg per metric ton for the modern plants. These emissions can be reduced further (by 30 to 50 percent) by well-maintained equipment and good operating procedures by personnel.

Emissions from petroleum-solvent plants can be as high as 154 kg of solvent per metric ton of textiles. Although there are adsorption units commercially available for petroleum-solvent machines, none have been installed to date. However, it is estimated that these adsorption units are capable of recovering as much as 95 percent of the evaporated petroleum solvents.

Control Technology and Costs. The dry cleaning industry contributes to air pollution by the release of organic-solvent vapors to the atmosphere. The amount of solvent emitted to the atmosphere from any one dry cleaning plant is dependent upon the equipment design solvent used, the length of certain operations in the cleaning process, the precautions used by the operating personnel, and the quantity of clothes cleaned. The most important of these items are the precautions used and the weight of the clothes cleaned. Because of the higher capital investment required for emission controls on petroleum-solvent plants, it is believed that all new plants will use synthetic solvents, and that 50 percent of the petroleum-naptha solvent plants will shut down or convert to synthetic solvent operations by 1980. Futhermore, increasing solvent costs will provide an incentive for better evaporative emission control.

Annualized control costs and industry operating statistics are detailed in Table 3-38-1.

Table 3-38-1.
Dry Cleaning Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (Million MT/Yr)	1.29	1.74	2.05

Annual Growth Rate Over the Period 1976-85 = 4.94%

PROCESS CHARACTERISTICS	Model Plant Size (MT/Yr)	Pollutants Controlled	Control Technology
Synthetic Solvents	57	Hydrocarbons	Carbon Absorber
Petroleum Solvents	106	Hydrocarbons	Carbon Absorber
Switch from Petroleum to Synthetic	106	Hydrocarbons	Process Switch

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Hydrocarbons	161.47	187.13	184.49		
Legislated Controls:					
Hydrocarbons	96.09	74.65	92.42		
CONTROL COSTS (Million 1975 $)					
Investment	49.48	6.01	2.32	242.65	80.44
Total Annual	20.32	31.13	33.44	346.39	302.74
Capital	20.32	31.13	33.44	346.39	302.74
O&M	0	0	0	0	0

INDUSTRIAL AND COMMERCIAL HEATING

Operating Characteristics and Capacities. The majority of commerical and industrial heating is accomplished by hot water and steam boilers. Although hot air furnaces are utilized for space heating, these units are fired on gas or distillate oil and they generally do not contribute significantly regional air pollution.

Commercial equipment normally is defined as having a capacity in the range of 0.05 to 2.11 million kg cal per hour. Industrial equipment normally is defined as equipment having a capacity in the range 2.11 to 169 million kg cal per hour. These ranges are loosely defined and in practice they often overlap; the equipment size distribution by location and fuel type is not available.

The estimated 1974 installed capacity of commercial and industrial boilers is 10 x 10^{15} kg cal per year based upon a 1967 inventory and assumed growth rates of 4.5 percent per year for commercial units and 4 percent per year for industrial units.

Emission Sources and Pollutants. Pollutants emitted by fossil-fuel combustion are a function of fuel composition, efficiency of combustion, and the specific combustion equipment being used. Particulate levels are related to the ash content of the fuel, and sulfur oxides levels are related to the sulfur content of the fuel. Emissions of nitrogen oxides result not only from the high-temperature reaction of atmospheric nitrogen and oxygen in the combustion zone, but also from partial combustion of the nitrogenous compounds contained in the fuel; thus, levels are dependent both on combustion equipment design and upon fuel nitrogen. Carbon monoxide, hydrocarbon, and particulate levels are dependent on the efficiency of combustion as it is affected by combustion equipment design and operation. Accordingly, natural gas and distillate oil are considered clean fuels because of their low ash and sulfur contents, and also because they are relatively easy to burn. In contrast, coal (and some residual oils) contain significant amounts of sulfur and ash, require more sophisticated combustion equipment, and are more difficult to burn than the clean fuels.

The estimated uncontrolled emission factors and average emission factors, as required by the State Implementation Plans (SIP) for commercial and industrial boilers, are listed below and they are based on the following assumptions and conditions:

- The sulfur contents of coal, residual oil, and distillate oil are assumed to be 3, 2, and 0.2 percent by weight, respectively.
- The ash content of coal is assumed to be 12 percent by weight.
- The difference in particulate emissions factors between commercial and industrial coal-burning installations probably is related to differences in equipment design.

In the following tabulation of emissions factors, the factors within parenthesis indicate those required or allowed by SIP where applicable:

Emission Factors (kg per million kg cal)

Commercial	Particulates	Sulfur Oxides
Coal	1.8 (1.08)	8.6 (5.8)
Residual Oil	0.29 (1.08)	4.0 (2.0)
Distillate Oil	0.18 (1.08)	0.36 (0.43)
Gas	0.032 (1.08)	0.0011
Industrial		
Coal	11.7 (0.63)	8.6 (5.7)
Residual Oil	0.29 (0.63)	4.0 (2.0)
Distillate Oil	0.18 (0.63)	0.36 (0.43)
Gas	0.031 (0.63)	0.0011 --

Control Technology and Costs. It is apparent that equipment fired with gas and distillate oil essentially meets all of the air pollution regulations. The most cost-effective control technology has been switching from coal and high-sulfur residual oil to the less-polluting fuels. The current shortages and projected price rises for natural gas and distillate oils, and the proposed ban on switching to these fuels will require implementation of other control technologies in many cases.

Estimates of control costs are based on the assumption that for commercial boilers, fuel switching from coal and high-sulfur residual oil to low-sulfur residual oil is attainable, and that for industrial boilers, fuel switching from high-sulfur residual oil to low-sulfur residual oil is attainable. Alternative control technologies for coal-fired industrial boilers include dual alkaline scrubbers for sulfur oxides and particulates control. For the coal-fired boilers, flue gas treatment appears plausible for the larger units, while fuel switching appears realistic for the smaller ones. However, because no boiler size distribution was available at this time, all industrial coal-fired boilers were assumed to be using flue gas treatment as a control technology; this assumption will overstate the control costs.

Because of the present instability and future uncertainty of fuel prices, no attempt was made to account for the cost differential among fuels. On a Btu or heating value basis, there could be little difference in costs. Although it appears that the cost of coal and high-sulfur residual oil would be lower than the cost of the clean fuels prior to firing in a boiler, the higher costs of handling the coal and high-sulfur residual oil, as well as the higher equipment maintenance costs, are judged to offset any price differential. The net effect of these considerations would produce virtually equivalent fuel costs on a consistent basis.

The estimated control costs for the model heating plants are given in Table 3-39-1. Investments and annualized costs are considerably lower for commercial than industrial installations because of the relative ease of fuel switching compared to the use of sophisticated flue-gas cleanup systems.

Table 3-39-1.
Industrial & Commercial Heating Industry Data Summary

ACTIVITY LEVEL	1975	1980	1985
Capacity (MT/Hr)			
Industrial	301,637	386,962	455,758
Commercial	130,471	141,737	171,532

Annual Growth Rate Over the Period 1976-85 = Industrial 5.05%
Commercial 4.40%

PROCESS CHARACTERISTICS	Model Plant Sizes	Pollutants Generated	Control Technology
Industrial Commercial	N/A	Particulates Sulfur Oxides Nitrogen Oxides Hydrocarbons Carbon Monoxide	ESP & FGD Fuel Switching

EMISSIONS (1,000 MT/Yr)	1975	1980	1985	1971-85	1976-85
1971 Controls:					
Combustion of Coal:					
Particulates	2,192.12	3,020.69	3,753.83		
Sulfur Oxides	3,644.91	4,977.24	5,898.31		
Nitrogen Oxides	709.71	979.03	1,158.08		
Hydrocarbons	44.54	59.10	71.09		
Carbon Monoxide	113.78	151.46	180.32		
Combustion of Oil:					
Particulates	302.47	398.56	460.10		
Sulfur Oxides	3,767.63	4,975.44	5,808.50		
Nitrogen Oxides	835.15	1,097.84	1,276.14		
Hydrocarbons	42.01	55.17	64.76		
Carbon Monoxide	56.07	73.74	85.75		
Combustion of Natural Gas:					
Particulates	78.02	117.77	129.89		
Sulfur Oxides	3.39	4.06	4.47		
Nitrogen Oxides	858.69	1,011.36	1,099.42		
Hydrocarbons	21.78	27.33	31.06		
Carbon Monoxide	94.68	114.27	126.45		

Table 3-39-1. (Continued)
Industrial & Commercial Heating Industry Data Summary

EMISSIONS (1,000 MT/Yr)	1975	1980	1985
Combustion of Distilled Oil:			
Particulates	58.50	83.50	102.70
Sulfur Oxides	117.00	167.01	205.41
Nitrogen Oxides	239.84	342.37	421.09
Hydrocarbons	12.28	17.54	21.57
Carbon Monoxide	16.38	23.38	28.76
Legislated Controls:			
Combustion of Coal:			
Particulates	1,020.85	242.39	288.06
Sulfur Oxides	2,837.62	1,755.62	1,972.63
Nitrogen Oxides	736.38	1,015.52	1,186.65
Hydrocarbons	45.72	61.37	72.29
Carbon Monoxide	116.38	154.91	182.97
Combustion of Oil:			
Particulates	314.11	409.79	477.92
Sulfur Oxides	3,938.61	5,184.42	6,068.11
Nitrogen Oxides	804.40	911.87	1,055.23
Hydrocarbons	43.48	56.50	64.99
Carbon Monoxide	58.03	75.38	86.78
Combustion of Natural Gas:			
Particulates	101.21	121.06	132.55
Sulfur Oxides	3.51	4.18	4.57
Nitrogen Oxides	893.65	1,043.56	1,125.72
Hydrocarbons	22.44	27.87	31.47
Carbon Monoxide	98.16	117.37	128.92
Combustion of Distilled Oil:			
Particulates	58.90	83.20	102.42
Sulfur Oxides	117.80	166.40	204.84
Nitrogen Oxides	241.49	341.13	419.92
Hydrocarbons	12.37	17.47	21.51
Carbon Monoxide	16.49	23.30	28.67

Table 3-39-1. (Continued)
Industrial & Commercial Heating Industry Data Summary

EMISSIONS (1,000 MT/Yr)	1975	1980	1985		
CONTROL COSTS (Million 1975 $)					
Investment					
Industrial	1,737.97	153.55	141.04	11,012.19	6,537.22
Commercial	722.31	350.60	83.00	3,756.23	1,737.49
Total Annual	1,710.83	2,940.86	3,269.45	32,077.26	28,259.99
Capital	1,033.31	1,768.67	1,896.69	19,073.51	16,762.00
Industrial	796.19	1,390.25	1,455.48	14,924.53	13,124.39
Commercial	237.12	378.42	441.21	4,148.98	3,637.61
O&M	677.52	1,172.19	1,372.76	13,003.75	11,497.99
Industrial	269.79	505.29	565.87	5,446.88	4,850.12
Commercial	407.73	666.90	806.89	7,556.87	6,647.87

Chapter 4
Mobile Source Pollution Control

1. MOBILE SOURCE EMISSION CONTROLS

Introduction

Mobile sources are recognized as significant contributors to national air-quality problems. In areas subject to photochemical smog formation, over half the reactants can generally be attributed to motor-vehicle emissions. Similarly, motor-vehicle emissions frequently cause large concentrations of carbon monoxide in high-traffic-density urban areas during traffic peaks. In cities with large and busy commercial airports, aircraft operations are often the source of high levels of carbon monoxide, hydrocarbons, nitrogen oxides, and particulates in the vicinity of the runways and terminals.

Passenger cars and light-duty trucks have been highly significant and visible pollutant sources because of the large numbers in service. Consequently, they have been under Federal controls since the 1968 models. Federal controls on heavy-duty motor vehicles engines have been in effect since 1970, and controls on aircraft emissions went into effect in 1974.

Other mobile sources, such as railroad locomotives, marine engines, and farm, construction, and garden equipment, have been under study by EPA, but to date, no regulations for these sources have been promulgated or proposed. Motorcycle emissions control regulations become effective in 1978, but cost factors were not developed soon enough to be included in this report.

Review of Recent Factors Affecting Mobile Sources

The oil crisis of late 1973 and early 1974 resulted in a trend toward smaller cars and increased gasoline prices. It also resulted in increased emphasis on fuel economy, which has affected the present and future emission control strategies.

The recession of late 1974 resulted in a drastic reduction in new-car sales for the last half of 1974, which continued into 1975.

The Energy Supply and Environmental Coordination Act of 1974[1], passed by Congress on June 22, 1974, included a provision which delayed the scheduled 1976 and 1977 emission standards. With less stringent emission standards for these 2 years, the cost and fuel consumption penalties will be less than estimated in the last Cost of Clean Air Report.

The changes in light- and heavy-duty truck regulations call for trucks in these two classes to meet more stringent emissions standards. The light truck class has been enlarged to include all trucks under 8,500 pounds gross vehicle weight. (The prior definition applied to trucks under 6,000 pounds.)

As provided for in the 1970 Clean Air Act and Amendments, the auto companies filed requests for suspension of the 1977 emission standards early in January of 1975. The decision was made to grant the request for suspension of the 1977 hydrocarbon and carbon monoxide emission standards, and to establish interim standards for the 1977 model year at the level of the current 1975-76 hydrocarbon and carbon monoxide standards. The 1977 legislated nitrogen oxide standard of 2.0 grams per mile (g./mile) was not affected.

The 1977 amendments to the Clean Air Act call for maintaining 1977 standards through the 1979 model year. The CO standards are 7.0 in 1980 and 3.4 for 1981-85. NOx is set at 1.0 for 1980-85, and HC at 0.41 for the same period.

Light-Duty Vehicle Controls

EMISSION STANDARDS

Since 1968, the Federal Government has regulated the output of air pollutants from the exhaust of new light-duty motor vehicles. Emission standards are expressed in terms of maximum levels of gaseous emissions per mile permitted from the vehicle while operating on a prescribed duty cycle. Sampling procedures and test equipment are also prescribed by the regulations.

Both emission levels and test procedures have been revised periodically in several steps of increasing stringency. Changes in the Federal Test Procedure were implemented for the 1972 and 1975 model years. Changes in emission levels were prescribed by the Environmental Protection Agency (or its predecessors) for 1970 and 1973 (nitrogen oxides), and were based largely on evolving technology for emission control.

The 1970 Amendments to the Clean Air Act called for the Administrator to prescribe Federal emission standards for 1975 and later year models effecting a 90 percent reduction in the hydrocarbon and carbon monoxide emissions from 1970 levels, and to prescribe the Federal standards for 1976 and later year models effecting a 90 percent reduction in nitrogen oxide emissions from 1971 levels. The 1970 Amendments further gave the Administrator the authority to grant a 1-year suspension of the 1975 and 1976 standards under specified conditions if it could be established that effective control technology was not available for compliance.

After extensive hearings in March 1973, the Administrator found that, although the necessary technology existed to meet the 1975 standards through the use of catalytic converters, there was a high degree of uncertainty concerning the industry's ability to certify and produce catalyst-equipped cars in 1975 in large enough numbers to meet production requirements for their full model line. In addition, in-use reliability of the catalysts had not been established. Because of this, it was found that the risk of introducing catalysts on all vehicles in 1975 outweighed the risk to human health if the standards were delayed. The suspension was applied in two parts:

- National 1975 interim standards were established which were more strict than standards previously in force, but which were not anticipated to necessarily require catalysts on the majority of vehicles sold.

- More stringent standards were allowed for vehicles sold only in California, which would require catalysts on cars sold in that state. Under the California waiver provision in the Clean Air Act, the state was permitted to establish its own hydrocarbon and nitrogen oxide standards. A Federal standard that is more stringent than that applicable to cars sold elsewhere was prescribed for carbon monoxide.

The 1975 statutory standards as originally established were to be applicable to all cars sold in the United States in 1976.

Similarly, the Administrator suspended the statutory NOx standards for 1976 and later models, on July 31, 1973. This decision was based on the belief that technological success in meeting the 1976 statutory standards could not be reasonably predicted. In applying this suspension, the Administrator established an interim nitrogen oxide Federal standard of 2.0 g./mile, which is attainable with existing advanced emission-control technology.

Finally, the aforementioned Energy Supply and Environmental Coordination Act of 1974 and the 1977 amendments to the Clean Air Act further delayed the light duty passenger car requirements, as shown in Table 1-1.

Table 1-1.
Federal Exhaust Emission Standards and Control Levels for Light-Duty Vehicles[1] by Model Year

Under 6,000-lb Gross Vehicle Weight

Type of Vehicle	Pre-1968[2] HC	CO	NOx	1970 HC	CO	NOx	1973/1974 HC	CO	NOx	1975/1976 HC	CO	NOx	1977/1979 HC	CO	NOx	1980/1985[3] HC	CO	NOx
							Emissions expressed in grams per mile											
Light-duty gasoline passenger car	8.7	87	4.0	4.1	34	--	3.0	28	3.1	1.5	15	3.1	1.5	15	2.0	0.41	3.4[3]	1.0[3]
Light-duty diesel passenger car	--	--	--	--	--	--	--	--	--	1.5	15	3.1	1.5	15	2.0	0.41	3.4	1.0
Light-duty gasoline truck	--	--	--	--	--	--	3.0	28	3.1	2.0	20	3.1	2.0	20	3.1	2.0[4]	20[4]	3.1[4]
Light-duty diesel truck	--	--	--	--	--	--	--	--	--	2.0	20	3.1	2.0	20	3.1	2.0[4]	20	3.1[4]

[1] Emission levels as measured on the 1975 FTP.

[2] Estimated levels before controls.

[3] 1980 standards for CO are 7.0, and for NOx are 2.0

[4] Standards assumed are those used for determining cost of compliance in this report. Actually promulgated standards for 1979 and later model years are HC = 1.7, CO = 18, NOx = 2.3 grams per mile.

PASSENGER CARS

Control Devices, 1968-1974 Model Years. From 1968 to 1974, compliance with Federal emission standards was achieved by utilizing various combinations of the following:

- Purging of crankcase fumes through the engine
- Recalibration and tighter precision of carburetor fuel metering
- Engine intake air preheat and temperature control
- Spark retard at idle and low speeds
- Reduced compression ratios and elimination of combustion chamber pockets
- Air injection into the exhaust manifold
- Changes in valve timing and recirculation of exhaust gases
- Capture of fuel evaporative emissions in charcoal canisters or in the crankcase.

Table 1-2 summarizes the EPA and NAS estimates for incremental cost increases per car due to emission control requirement for the period 1968 to 1974. These data, taken from the 1974 Cost of Clean Air Report, are expressed in current dollars.

Estimates of the aggregate initial-equipment or engine modification costs per car for emission control through 1974 (expressed in December 1974 dollars) are $100 (EPA) and $84 (NAS). Industry estimates for that same period are $50-$120 (expressed in December 1974 dollars).

Table 1-2.
Estimated Passenger Car Emission-Control Equipment Cost, 1968-74

Model Year	Item	List Price[1] EPA[2]	NAS[3]
1968-69	Positive crankcase ventilation (PCV) valve	$ 0.40	$ 2.85
	Inlet air temperature control	5.00	3.80
	Cumulative cost through 1969	$ 5.40	$ 6.65
1970-72	Fuel evaporation control system	13.50	14.30
	Idle control solenoid	11.10	4.75
	Carburetor changes	3.00	0.95
	Hardened valves and seats (for unleaded gasoline)	2.00	1.90
	Transmission control system	--	3.80
	Ignition timing	--	0.95
	Choke heat bypass	--	4.18
	Compression ratio changes	--	1.90
	Cumulative costs through 1972	$35.00	$39.38
1973-74	Exhaust gas recirculation (EGR), 11-14 percent	26.00	9.50
	Speed controlled spark timing	26.00	0.95
	Precision cams, bores, pistons	--	3.80
	Transmission changes	--	0.95
	Cumulative costs through 1974	$87.00	$54.53

[1] List price includes both dealer and manufacturers profits, expressed in current dollars.

[2] From Reference 7.

[3] From Reference 8.

Control Devices, 1975-1976 Model Years. When the 1975 Statutory Standards were suspended for 1 year[9] and replaced with less stringent interim standards, it became apparent that two types of emission-control systems could be used for the 1975 model year. These were: (1) oxidation catalyst-equipped systems, and (2) advanced engine modifications systems. The oxidation catalyst systems have been preferred by the industry, and approximately 85 percent of the 1975 model year sales included catalysts. Other changes and additions for some 1975 model-year cars included:

- Quick-heat manifold
- High-energy ignition
- Advanced carburetors
- Air injection.

Since the 1976 emission standards[10] called for the same hydrocarbon, carbon monoxide, and nitrogen oxide levels as the 1975 interim standards, only minor changes in emission control systems were made from 1975 models. Proportional exhaust gas recirculation was introduced in some models.

Estimates of the initial equipment or engine modification costs per car for emission control for the 1975 and 1976 model years are $200 (EPA estimate in 1975 dollars), $159 (NAS), and $100-$450 (Industry).

Control Devices, 1977 Model Year. With the suspension of 1977 emission standards on March 5, 1975, and the setting of interim standards for hydrocarbon and carbon monoxide at the 1975-76 levels, and nitrogen oxide at a level of 2.0 g./mile (which is 35 percent lower than the 1975-76 level), the automobile companies met the 1977 standards with only minor modifications to engines and control devices. These modifications took the form of increased use of secondary air for catalyst operation, improved exhaust gas recirculation, ignition timing modification, or modified catalysts with decreased use of secondary air. EPA has estimated the incremental cost to meet 1977 emission standards at $15.

Control Devices, 1978 and 1979 Model Years. Since Congress has passed Clean Air Act Amendments calling for maintenance of 1977 emission levels through the 1979 model years, cumulative control costs per vehicle are maintained at the 1977 level for their cost analyses. This results in significant cost reduction over previous 1978 standards at the expense of increased emissions to the environment.

In addition to the modifications applied earlier, standards would require application of a three-way (HC, CO, NOx) catalyst, plus electronic control modules for the following items: spark control, exhaust gas recirculation, air-to-fuel ratio, and air injection. Costs for these modifications would vary with size of vehicles, engine design, engine calibration, etc. EPA's estimate of 1980 incremental costs for an "average" vehicle is $220 for 3.4 g/mi. CO or $163 for a 9 g/mi. CO standard (1974 dollars).

Summary of Estimated Emission Control Equipment Costs. Table 1-3 summaries the various estimates for incremental cost increases per car due to emission control requirements for the period 1968 to 1985; data in this table were obtained primarily from Reference 11.

Table 1-3.
Estimated Passenger Car Emission-Control Equipment Costs, 1968-1980 Model Years

	List Price[1] (December 1974 Dollars)		
Model Year	EPA[3]	NAS[3]	Industry[2]
Cumulative costs through 1974[4]	100	84	50-120
1975/76 incremental costs	100	75	50-330
1977 incremental costs	15	--	--
1978 incremental costs	0	145	215-500
1980 incremental costs	220	--	--
Cumulative costs through 1985	435[5]	304	315-950

[1] List price includes dealer and factory profits.
[2] From data submitted by the domestic manufacturers.
[3] Data obtained primarily from Reference 11.
[4] Restated from Table 1-2 in 1974 dollars.
[5] $456 in 1975 dollars.

Estimated Maintenance Costs Due to Emission Controls. The additional per vehicle maintenance costs attributable to emission-control devices has been estimated by EPA to be $16 per year from model years 1968 through 1974. For the 1975, 1976, and 1977 model years, there are certain benefits in reduced maintenance cost derived from the use of high-energy ignition systems, long-life exhaust systems, and unleaded fuel. For the 1975-77 model years, the annual maintenance cost benefits are estimated to be $23 per catalyst-equipped car over 1974 cars; thus, the net maintenance cost over the pre-controlled cars is a $7 benefit.

Additional maintenance costs are anticipated for the 1980 and later model years because of the greater complexity expected in the emission control systems required to meet the lower hydrocarbon and carbon monoxide standards. This increase over 1975 cars is estimated to be $8 per car, resulting in a net annual maintenance cost of $1 per car, or about the same as pre-controlled cars.

Annual maintenance cost penalties for the various model years are shown in Table 1-4. The estimated costs for 1975 through 1977 are based on assuming that 85 percent of vehicles sold in the United States in 1975 were catalyst-equipped, 80 percent in 1976, and 75 percent in 1977. Recent data show that use of catalysts in 1976 and 1977 remained at the 85 per cent level.

Table 1-4.
Estimated Incremental Maintenance Costs for Passenger Car Emission Control Systems, 1968-1980 Model Years

Model Year	Annual Incremental Maintenance Cost Increase (Decrease) per Vehicle[1]	Net Costs
1968-74	$16	$16
1975-79	(23)[2]	(7)
1980-81	7[3]	0
1982-85	0	0

[1] Additional cost over normal maintenance due to emission control. 1968-74, current dollars; 1975-80, December 1974 dollars.

[2] Assuming oxidation catalysts used all five model years, and based on 1975 interim standards (1.5 HC, 15 CO, 3.1 NOx).

[3] Assuming dual catalysts (oxidation plus reduction) to be used, and based on HC, CO, and NOx levels of 0.41, 3.4, and 1.0. One catalyst change in 10 years assumed.

FUEL-CONSUMPTION PENALTIES

The average fuel economy of motor vehicles decreased gradually from the 1968 through the 1974 model cars. This change can be attributed to variations in vehicle weight, engine size, optional equipment, and the effects of emission-control equipment. In particular, the specific emission-control measures that adversely affect fuel consumption are retarded ignition timing, reduced compression ratio, and exhaust-gas recirculation.

Fuel economy penalties for the 1968 to 1973 model years were obtained from an EPA study of passenger car fuel economy involving tests of nearly 4,000 vehicles ranging from 1957 production models to 1975 prototypes. The fuel economy for 1973 model cars decreased over pre-1968 cars by about 10.1 percent. For 1974 models, fuel economy decreased 10.4 percent from the pre-1968 baseline, based upon estimates from 1974 certification data and 1974 sales data for the first 6 months. A shift toward lighter cars was observed in the first 6 months sales, but the trend was reversed for the remainder of the year.

Various industry sources as well as the EPA have indicated that catalytic systems on most 1975 vehicles resulted in fuel economy superior to 1973 and 1974 model-year cars. The EPA-measured fuel economy data for 1975 certification vehicles, when weighted for the estimated vehicle sales, resulted in a gain of 12.2 percent over 1974 models, or a slight fuel economy benefit over pre-1968 baseline data of approximately 1.0-2.0 percent.

An additional fuel economy improvement was shown in the 1976 model year, resulting in an estimated fuel economy gain of about 12.8 percent over pre-1968 cars. No change in fuel economy is anticipated for the 1977 model year (when the NOx standard drops from 3.1 to 2.0 g./mile) due to the expected extensive use of proportional exhaust gas recirculation (PEGR) and other technological improvements.

It is assumed that by adopting optimal-fuel strategies for the 1980 model year that a fuel economy improvement of about two percent will occur due to improved combustion conditions.

No additional fuel economy gains or penalties are estimated for model years 1980 through 1985 due to emission controls. In separate efforts to improve fuel economy, the auto companies are reducing the size and weight of vehicles in their existing model line, improving engine efficiency, changing axle ratios, and introducing new lighter, smaller models. These projects will raise the average fuel economy of all affected models, regardless of the potential effect of pollution controls. The principal impetus for these developments is the Energy Policy and Conservation Act (P.L. 94-163) passed and signed in December 1975 that required all manufacturers to meet fuel economy standards (on the average) of 18, 19 and 20 miles per gallon for their 1978, 1979, and 1980 models, respectively. The effect of emission controls on passenger-car fuel economy for the period 1968 to 1985 is summarized in Table 1-5. Fuel economy data were obtained from References 12, 13, and 14.

Table 1-5
Effect of Emission Controls on Fuel Economy of the Average Passenger Car[1]

Model Year	Change in MPG of the Model Year Cars Due to Controls
1967	0.0
1968	-0.65
1969	-0.28
1970	0.34
1971	-0.35
1972	-0.22
1973	-0.43
1974	-0.04
1975	1.87
1976	1.89
1977	0.0
1978	0.0
1979	0.0
1980	0.0
1981	0.0
1982	0.0
1983	0.0
1984	0.0
1985	0.0

[1] Baseline fuel economy of 1967 model year car (combined cycle city-highway) = 15.5 mpg. All percentages shown are based on Urban Cycle Fuel Economy tested on the 1975 EPA Federal Test Procedures.

LIGHT-DUTY TRUCKS

For this report, it is assumed that emission control equipment costs for light-duty trucks are the same as for passenger cars for 1973 and 1974. Beginning with the 1975 model year, less stringent standards were set for light-duty trucks than for passenger cars. Consequently it is assumed in this report that emission control costs for model years 1975-85 will be only moderately higher ($150 per car in December 1974 dollars) than for the 1973-74 model years.

Annual maintenance costs for 1973 and 1974 model year light-duty trucks are estimated to be $16 per vehicle. For the 1975 to 1985 model year period, it is estimated that there will be a maintenance cost benefit of $5 per vehicle due to the use of catalysts, low-maintenance emission-control components, and unleaded fuel in a significant portion of light-duty trucks sold in that period.

Fuel economy of light-duty trucks is expected to be the same as for light-duty passenger cars for 1973 and 1974. A fuel economy gain of 6 percent is estimated for the 1975 model year, and no change for the 1976 to 1985 period.

The costs calculated in this report all assume that current regulations for light-duty trucks will remain the same. However, EPA recently made two significant changes to existing regulations beginning with the 1979 model year, which are not analyzed in this report. First, the size of the light-duty truck class was increased from the present class which includes all trucks with gross vehicle weight ratings of 0 to 6,000 pounds to an expanded class to include all trucks weighing between 0 and 8,500 pounds. Second, emissions standards for light trucks were reduced slightly from existing levels. These changes tend to increase the cost estimates made in this report for the years 1978 to 1985. All 6,000- to 8,500-pound trucks that are currently considered heavy-duty trucks and are controlled to less stringent standards must be equiped with additional pollution control devices, though the 0 to 6,000-pound trucks should not require any additional equipment to meet the lower standard. No change in fuel economy is expected due to this action.

FUEL COST INCREASES

Two EPA regulations affecting fuel costs are discussed below. One pertains to requiring gasoline marketers to make available 91 research octane number lead-free gasoline by

July 1, 1974, for use in oxidation catalyst-equipped vehicles. The other EPA regulation required that the lead content of leaded gasoline be reduced to an average of 0.5 grams per gallon (g./gal.) by October 1979. This latter regulation, aimed at reducing lead in the atmosphere for health purposes, was recently upheld by the courts as discussed earlier in this chapter. Thus, for the purposes of this report, it is assumed that lead phase-down will take place as called for by EPA. The promulgated schedule stretches the lead removal over a relatively long period of time.

AGGREGATE NATIONAL COSTS FOR LIGHT-DUTY VEHICLE EMISSION CONTROLS

Costs to the nation for light-duty vehicle emission control will be comprised of the aggregate of equipment, maintenance, and fuel-consumption cost increments attributable to the control devices. Since the various costs attributable to emission controls are different for each model year, total costs to the nation have been estimated separately for each model year using vehicle-population data for previous years and projections for future years.

Vehicle Population Estimates. Registration data[16] are available at this time for vehicle model years up to 1974 for each calendar year through 1974. Estimates of vehicle populations for future years are based on the U.S. passenger-vehicle sales projections[17] shown in Table 1-6. These projections reflect the major downturn in new-car sales which began late in 1973. Using these projections and typical scrappage-rate histories[18,19] for previous model years, the vehicle population trends shown in Figure 1-1 are estimated. As shown, uncontrolled passenger vehicles will constitute only about 5 percent of the population by 1980, and 92 percent of the vehicles will have been manufactured under controls imposed by the Clean Air Act Amendments of 1970.

Table 1-6.
Historical and Projected Sales of Passenger Vehicles

Model Year	Sales (Millions of Vehicles)
1968	9.40
1969	9.53
1970	8.46
1971	9.96
1972	10.61
1973	11.46
1974	8.9
1975	8.6
1976	10.7
1977	10.4
1978	9.1
1979	9.8
1980	11.8
1981	12.6
1982	12.5
1983	12.6
1984	12.8
1985	12.3

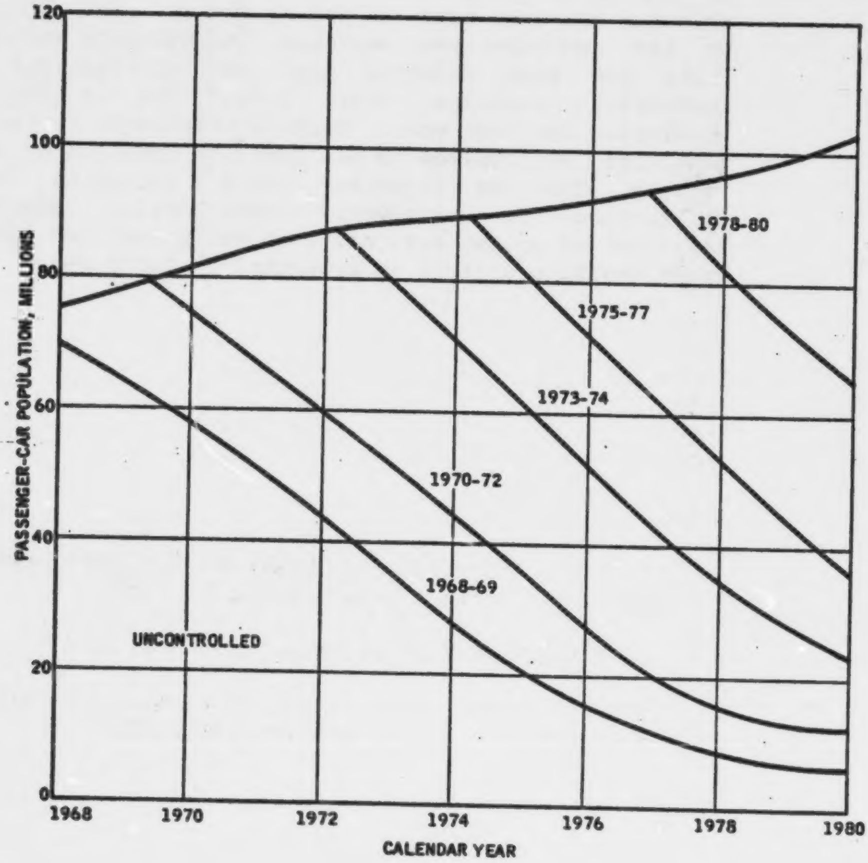
Notes:

1. 1968 to 1973 sales data based on data from Automotive News 1974 Almanac Issue, April 24, 1974.

2. 1974 sales, Automotive News, March 3, 1975.

3. 1977-85 predicted sales from the Chase Econometric Associates study for EPA/CEQ, June 1977.

Figure 1-1.
Estimated Passenger-Car Population



In estimating light-duty truck population, it is assumed that survival factors for presently registered light trucks will be slightly higher than those for passenger cars[20], and that new registrations of light trucks will follow the same pattern as passenger cars for the interval 1974-85.

Estimated Total Costs, 1968-1985. A breakdown of annual national cost estimates for passenger car emission control is presented in Table 1-7. Equipment costs for each calendar year are taken as the equipment cost attributable to the new model-year vehicles. Maintenance and equipment costs for each calendar year are attributable to all controlled vehicles over 1-year old in the vehicle population for that year. Costs attributable to fuel price penalties are applied to all gasoline consumed by passenger vehicles for the affected years (assuming continued utilization of catalytic converters). Similarly, a breakdown of annual national cost estimates for light-duty truck emission control is presented in Table 1-8.

Table 1-7.
Estimated National Costs Attributable to Light-Duty Passenger Car Emission Controls, 1968-1985

Annual Incremental Expenditures (Billions of Dollars[1])

Calendar Year	Equipment	Maintenance	Fuel Consumption Penalty[2]	Fuel Price Penalty[3]	Annual Total	Cumulative Total
1968	0.09	0.27	0.21	--	0.57	0.57
1969	0.09	0.52	0.28	--	0.89	1.46
1970	0.47	0.69	0.15	--	1.31	2.77
1971	0.56	0.90	0.25	--	1.71	4.48
1972	0.53	1.12	0.31	--	1.96	6.44
1973	1.27	1.31	0.43	--	3.01	9.45
1974	0.90	1.42	0.50	--	2.82	12.27
1975	1.73	1.07	(0.14)	0.07	2.73	15.00
1976	2.35	0.86	(0.94)	0.24	2.51	17.51
1977	2.45	0.68	(0.81)	0.36	2.68	20.19
1978	2.15	0.50	(0.72)	0.51	2.44	22.63
1979	2.31	0.31	(0.67)	0.67	2.62	27.87
1980	3.82	0.14	(0 69)	0.88	4.07	31.94
1981	5.75	0.03	(0.65)	1.10	6.23	38.17
1982	5.70	(0.04)	(0.64)	1.28	6.30	44.47
1983	5.74	(0.15)	(0.60)	1.37	6.36	50.83
1984	5.84	(0.17)	(0.55)	1.41	6.53	57.36
1985	5.61	(0.17)	(0.35)	1.43	6.52	63.88
1968-85[4]	47.4	9.29	(4.63)	9.32		
1976-85	41.72	1.99	(6.62)	9.25		

Table 1-7.
Estimated National Costs Attributable
to Light-Duty Passenger Car Emission
Controls, 1968-1985

Annual Incremental Expenditures (Billions of Dollars[1])

[1] Current dollars used for 1968-74; December 1975 dollars used for 1975-85. Interest is not applied to annual expenditures.

[2] Fuel prices assumed: 1968, 43.0 cents/gal.; 1969, 44.0 cents/gal.; 1970, 45.0 cents/gal.; 1971, 45.0 cents/gal.; 1972, 43.0 cents/gal.; 1973, 43.0 cents/gal.; 1974-75 55 cents/gal.; 1976, 60 cents/gal.; 1977, 60 cents/gal.; 1978, 61 cents/gal.; 1979, 62 cents/gal.; 1980, 63 cents/gal; 1981, 64 cents/gal.; 1982-83, 65 cents/gal.; 1984, 66 cents/gal.; 1985, 67 cents/gal.

[3] Based on fuel cost increase due to lead-free and phasedown regulations of 1.00 cents/gal. for 1975-76, 1.5 cents/gal. for 1976-77, and 1.7 cents/gal. for 1978; 1.9 cents/gal. for 1979; 2.1 cents/gal. for 1980; 2.3 cents/gal. for 1981; 2.5 cents/gal. for 1982-85.

[4] Totals may not equal the sum of tabular entries due to rounding.

Table 1-8.
Estimated National Costs Attributable to Light-Duty Truck Emission Controls, 1973-1985

Annual Incremental Expenditures[1] (Billions of Dollars[2])

Calendar Year	Equipment	Maintenance	Fuel Consumption Penalty[3]	Fuel Price Penalty[4]	Annual Total	Cumulative Total
1973	0.17	0.03	0.07	--	0.27	0.27
1974	0.13	0.05	0.21	--	0.39	0.66
1975	0.20	0.05	0.28	0.05	0.58	1.24
1976	0.26	0.04	0.38	0.07	0.75	1.99
1977	0.28	0.03	0.48	0.11	0.90	2.89
1978	0.26	0.02	0.57	0.14	0.99	3.88
1979	0.26	0.01	0.66	0.16	1.09	4.97
1980	0.29	0	0.76	0.22	1.27	6.24
1981	0.29	(0.01)	0.87	0.25	1.40	7.64
1982	0.29	(0.02)	0.98	0.28	1.53	9.17
1983	0.30	(0.03)	1.10	0.31	1.68	10.85
1984	0.30	(0.04)	1.22	0.35	1.83	12.68
1985	0.31	(0.05)	1.35	0.39	2.00	14.68
1973-85	3.34	0.08	8.43	2.33	14.68	
1976-85	2.84	(0.05)	8.37	2.28	13.44	

[1] Trucks less than 6,000 pounds gross vehicle weight. Interest is not applied to annual expenditures.

[2] Current dollars used 1973-74; December 1974 dollars used 1975-85.

[3] Fuel prices assumed: 1973, 41.6 cents/gal.; 1974-75, 55 cents/gal.; 1976, 61 cents/gal.; 1977, 63 cents/gal.; 1978, 65 cents/gal.; 1979, 67 cents/gal.; 1980, 69 cents/gal.

[4] Based on fuel cost increase due to lead-free and phasedown regulations of 1.09 cents/gal. for 1975-76 1.3 cents/gal. for 1977-79, and 1.5 cents/gal. for 1980.

Heavy-Duty Vehicle Controls

EMISSION STANDARDS

Separate emission-control regulations have been in effect since 1970 for new heavy-duty gasoline and diesel truck engines manufactured for use in over-the-highway trucks and buses of over 6,000 pounds gross vehicle weight. Trucks under 6,000 pounds gross vehicle weight are currently considered light-duty vehicles and have been dealt with in the previous paragraphs of this section. (Newly proposed regulations would increase the light-duty class to 8,500 pounds.) Heavy-duty truck engine emission test procedures are performed on the engine itself and do not pertain to the vehicle as in the case of light-duty truck and passenger car regulations.

Federal regulations for emissions from heavy-duty gasoline engines are shown in Table 1-10. For 1970 through 1973, regulations covered hydrocarbon and carbon monoxide emissions measured in terms of average concentrations in the engine exhaust over a nine-mode, constant-speed, variable-load dynamometer cycle. In 1974, new standards went into effect which are based on the same test procedure, but in which emissions are reported in terms of grams per horsepower-hour (g./hp-hr). The sum of hydrocarbon and nitrogen oxide emissions is limited to 16 g./hp-hr, while the standard for carbon monoxide is 40 g./hp-hr for 1974 and later model-year heavy-duty gasoline engines.

Heavy-duty diesel truck engine Federal standards are also shown in Table 1-10. Through 1970-73, standards covered smoke emissions only. In 1974, the standards were revised to include hydrocarbon, nitrogen oxide, and carbon monoxide emissions as well as more stringent smoke emissions. The permissible gaseous-emission levels are the same as for heavy-duty gasoline engines for 1974, but the test procedure is different. For diesels, emissions are averaged over a 13-mode, variable-speed, variable-load dynamometer cycle.

EPA is making changes to the heavy-duty engine standards and test procedures effective for model year 1979. Cost of control estimates made in this report do not reflect the implementation of these rules, nor do they reflect the change in the light-duty truck class to include all trucks with gross vehicle weights below 8,500 pounds. This regulation will reduce the size of the heavy-duty truck class subject to the heavy-duty standards and would therefore reduce the cost estimates for achieving heavy-duty emissions standards.

Table 1-9.
Federal Standards for Heavy-Duty Gasoline and Diesel-Engine Emissions

Pollutant	Emission Standards[1] 1970-73	1974
Gasoline Engines		
Hydrocarbons (HC)	275 ppm	16 g./hp-hr
Oxides of nitrogen(NO_x)	--	
Carbon monoxide (CO)	1.5 %	40 g./hp-hr
Diesel Engines		
Smoke:		
Opacity in accelerating mode	40%	20%
Opacity in lugging mode	20%	15%
Peak opacity in either mode	--	50%
HC + NO_x	--	16 g./hp-hr
CO	--	40 g./hp-hr

[1] For use in vehicles of more than 6,000 pounds gross vehicle weight.

HEAVY-DUTY GASOLINE ENGINE CONTROLS

The emission control technology used for heavy-duty gasoline engines through 1973 is similar to that employed for light-duty trucks and passenger cars through the 1972 model year. In fact, many heavy-duty gasoline engines are derivatives of passenger car engines. For 1974, the nitrogen oxide control standards were generally attainable without the use of EGR, although some EGR engines were certified in the previous year to meet California standards for 1973 which were at the same level as Federal standards for 1974.

No detailed equipment cost estimates have been made by EPA for heavy-duty gasoline truck engine emission controls. In the absence of such estimates, it is assumed for purposes of this report that the per-vehicle emission control equipment cost increment of 1970-73 engines is equivalent to that for 1970 model-year passenger car engines minus the cost of fuel evaporation controls, equalling $24 per vehicle. It is further assumed that the 1974 and following year control equipment costs will be equivalent to that for a 1973 passenger car engine less the cost of EGR and evaporative controls, or $50.00 per vehicle.

Incremental annual maintenance costs for heavy-duty gasoline truck engine controls for all years are assumed to be the same as passenger car costs for model years 1968 through 1974, or $16 per vehicle. Fuel consumption penalties are estimated to be 3 percent for the 1970-1973 period, and 5 percent for 1974 and beyond. A baseline fuel economy of 8.5 mpg is assumed. Estimates of total per-vehicle costs attributable to emission controls for this class of trucks are summarized in Table 1-10.

Table 1-10.
Estimated National Costs Attributable to Gasoline-Fueled Heavy-Duty Truck[1] Emission Controls, 1970-1985

Annual Incremental Expenditures[5] (Billions of Dollars[2])

Calendar Year	Equipment	Maintenance	Fuel Consumption Penalty[3]	Fuel Price Penalty[4]	Annual Total	Cumulative Total
1970	0.02	0.01	0.01	--	0.04	0.04
1971	0.02	0.02	0.03	--	0.07	0.11
1972	0.02	0.03	0.04	--	0.09	0.20
1973	0.02	0.05	0.07	--	0.14	0.34
1974	0.04	0.06	0.13	--	0.23	0.57
1975	0.04	0.08	0.17	0.09	0.38	0.95
1976	0.05	0.10	0.25	0.11	0.51	1.46
1977	0.05	0.11	0.31	0.16	0.63	2.09
1978	0.05	0.13	0.37	0.18	0.73	2.82
1979	0.05	0.14	0.44	0.19	0.82	3.64
1980	0.05	0.16	0.50	0.24	0.95	4.59
1981	0.05	0.18	0.55	0.28	1.06	5.65
1982	0.05	0.20	0.60	0.32	1.17	6.82
1983	0.05	0.22	0.65	0.36	1.28	8.10
1984	0.05	0.24	0.70	0.40	1.39	9.49
1985	0.05	0.26	0.75	0.44	1.50	10.99
1970-85	0.66	1.99	5.57	2.77	10.99	
1976-85	0.50	1.74	5.12	2.68	10.04	

[1] Trucks over 6,000 pounds gross vehicle weight.

[2] Current dollars used 1970-74; December 1974 dollars used 1975-1985.

[3] Fuel prices assumed: 1970, 44.3 cents/gal.; 1971, 43.4 cents/gal.; 1972, 41.5 cents/gal.; 1973, 41.6 cents/gal.; 1974-75, 55 cents/gal.; 1976, 61 cents/gal.; 1977, 63 cents/gal.; 1978, 65 cents/gal.; 1979, 67 cents/gal.; 1980, 69 cents/gal.

[4] Based on fuel cost increase due to lead-free and phasedown regulations of 1.09 cents/gal. for 1975-76, 1.3 cents/gal. for 1977-79, 1.5 cents/gal. for 1980.

[5] Interest not applied to annual expenditures.

It is estimated that the population of 1970-73 trucks of this class will peak at about 4.5 million in 1973, and that the total controlled population will have reached approximately 9.0 million in 1980. Estimated costs for heavy-duty gasoline truck Federal emission controls are presented in Table 1-11.

Table 1-11.
Estimated Per-Vehicle Cost Penalties for Heavy-Duty Gasoline Engine Emission Control

Incremental Cost Item	Model Years 1970-73 (1974 Dollars)	Model Years 1974-85 (1974 Dollars)
Emission-control equipment cost	$24	$50
Annual maintenance	16	16
Fuel consumption penalty[1]	3%	5%

[1] Based on 8.5 mpg for pre-1970 trucks.

HEAVY-DUTY DIESEL ENGINE CONTROLS

Both smoke and gaseous emission standards, including those for 1974, have been attained largely through fuel-injection system modifications. Nitrogen oxide and smoke are the more difficult emissions to control; even uncontrolled diesels are usually well within carbon monoxide standards. Equipment cost penalties are considered nominal; further, it is estimated that no fuel consumption penalties have been incurred. Accordingly, no national cost penalty is attributed to diesel-truck engine emission controls.

Aircraft Emission Controls

Aircraft emissions have been identified as significant contributors to the regional burden of pollution in comparison to other sources which will have to be controlled to meet National Ambient Air Quality Standards.

Airports are concentrated sources of pollutant emissions which will in many cases reduce local air quality to unsatisfactory levels even though emissions from automobiles and stationary sources are within acceptable levels within the general area. That is, unless aircraft emissions are reduced, airports will still remain intense area emitters of pollutants, even after emissions from other area sources have been greatly reduced.

The Clean Air Act directs the Administrator of the EPA to "establish standards applicable to emissions of any air pollutant from any class or classes of aircraft or aircraft engines which in his judgment cause or contribute to air pollution which endangers the public health or welfare." In July 1973, Federal emission standards and test procedures were established for various classes of new and in-use aircraft engines.[21] These regulations are based on the need to control emissions occurring under 3,000 feet to protect ambient air quality in urban areas. However, the standards are not quantitatively derived from the air quality considerations in affected areas but, instead, reflect EPA's judgment as to the emission levels that will be practicable with present and projected technology. The requisite technology is assumed to include advanced combustion-system concepts for turbine engines and improved fuel systems for piston engines. The standards cover (a) fuel venting regulations beginning January 1, 1974, (b) smoke emission regulations taking effect in 1974, 1976, and 1978 for various engine classes, and (c) gaseous emission (carbon monoxide, hydrocarbon, and nitrogen oxide) standards for 1979 and 1981. Gaseous emissions regulations are based on a simulated landing-and-take off operating cycle which includes: (1) taxi/idle (out), (2) take off, (3) climb out, (4) approach, and (5) taxi/idle (in). Piston engines are included in the standards beginning in 1979.

In general, the influence of the regulations will be to contribute to the maintenance of the quality of the air in and around major air terminals throughout the post-1979 era in which air traffic is undergoing expansion. Present aircraft emission standards[21] and their estimated cost impact[22,23] are listed in Table 1-12. Costs of fuel-venting and smoke emission controls through 1978, totaling $17 million, are minor in comparison to costs of controlling other sources in that time period.

Table 1-12.
Aircraft Emission Standards and Estimated Cost Impacts

Calendar Year	Standards	Implementation Technology	Estimated Cost of Implementation
1974	JT8D smoke standards.	Combustor and fuel nozzle retrofit.	Voluntarily completed. Cost not estimated
1974	Fuel venting restrictions for new and in-use engines (1975 for business-aircraft engines).	Plumbing and/or operational changes.	$2 million.
1976	Smoke standards, new turbine engines except JT3D, JT8D, and supersonic.	None, engines already comply	None.
1981	JT3D smoke standards.	Fuel nozzle retrofit.	$37.5 million.
1979	Gaseous emission (HC, CO, and NO_x) standards for all engines manufactured.	Modified engine hot section.	$66 million[1],[2]
1980	Same as 1979.	Same as 1979.	$5 million[2],[3]
1981-85	Gaseous emission standards for newly certified engines.	Advanced combustor and engine concepts.	$8 million
		1985 Cumulative Total	$93 million[2]

Sources: EPA, References 12 and 24.

[1] Principally development and recertification costs. Includes additional engine hardware costs which will be incurred in 1979. Maximum additional engine cost estimate to be:

$10,000 per large turbine engine
6,000 per small turbine engine over 8,000 lb thrust
2,000 per small turbine engine under 8,000 lb thrust, and per turboprop or APO engine
52 per piston engine.

[2] Estimated $2.9 million in piston engine fuel savings per year for 1979 and 1980 is included.

[3] Estimated $3.5 million for hardware and $1.5 million for certification.

The estimated cost of development and recertification efforts for compliance with the 1979 gaseous-emission standards is $66 million, and the additional engine-hardware costs, which will be incurred in 1979, are estimated to be $3.5 million. The costs incurred in 1980 for compliance with the 1979 standards are estimated to be $3.5 million for hardware and $1.5 million for certification for a total of $5.0 million. The 1979 standards promulgated for piston-type aircraft are expected to result in significant fuel savings: $29 million over 10 years. Credit for these savings has been assumed at a uniform rate of $2.9 million per year in estimating the cost of aircraft emission controls for 1979 and 1980. In total, cumulative national costs through 1980 for aircraft emission control are expected to total approximately $85 million (including $5.8 million for fuel savings).

Discussion of Unregulated Mobile Source Emission

As stated in the Introduction, a number of mobile sources are presently unregulated. These include: railroad locomotives, marine engines, and offroad farm, construction, and garden equipment.

Emission inventories have been performed on many of these unregulated mobile sources[25-28].

As a general conclusion, most small-engined mobile sources (such as garden equipment, outboard engines, and snowmobiles) each contribute less than 1 percent of the total hydrocarbon and carbon monoxide from mobile sources, and less than 0.1 percent of the total nitrogen oxide (based on 1970 data). While these percentages are increasing as passenger cars and trucks come under more stringent control, it would not appear to be cost-effective to regulate these mobile sources until some future time.

In a publication by HEW[29], it was estimated that the total carbon monoxide emissions from railroad locomotives in 1968 constituted about 1.6 percent of the emissions from all transportation sources. Percentages for hydrocarbon, total particulates, and sulfur oxides were 1.8, 16.7, and 12.5, respectively. At present, there are no proposed regulations for railroad locomotive exhaust emissions.

SUMMARY OF MOBILE SOURCE CONTROL COSTS

The preceding costs estimates for light and heavy duty trucks and aircraft source air pollution controls are expressed in December 1974 dollars, while the recently updated passenger car estimates are expressed in 1975 dollars. In order to convert to December 1975 dollars, an inflation rate of 8.7 percent was employed. Table 1-13 shows the major cost estimates expressed in 1975 dollars.

Table 1-13.
Estimated Total National Costs for Mobile Source Emission Control, 1968-1985

Annual National Investment and O&M Expenditures
(Billions of 1975 Dollars)

Year	Light-Duty Passenger Car Emission Control	Light Duty Truck Emission Control	Heavy-Duty Vehicle Emission Control	Aircraft Emission Control	Total Annual Cost
1968	0.57	--	--	--	0.57
1969	0.89	--	--	--	0.89
1970	1.31	--	0.05	--	1.36
1971	1.71	--	0.09	--	1.80
1972	1.96	--	0.11	--	2.07
1973	3.01	0.29	0.17	--	3.47
1974	2.82	0.42	0.41	--	3.49
1975	2.73	0.63	0.79	--	3.77
1976	2.51	0.81	0.55	--	3.87
1977	2.68	0.97	0.68	--	4.33
1978	2.44	1.07	0.79	0.02	4.32
1979	2.62	1.18	0.89	0.08	4.77
1980	4.07	1.37	1.03	--	6.47
1981	6.23	1.51	1.15	--	8.89
1982	6.30	1.65	1.27	0.002	9.22
1983	6.56	1.81	1.39	0.002	9.76
1984	6.53	1.98	1.51	0.002	10.02
1985	6.52	2.16	1.63	0.002	10.31
1968-85	61.46	15.85	11.97	0.108	89.38
1976-85	46.46	14.51	10.89	0.108	71.96

[1] Interest not applied to annual investments.

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2. TRANSPORTATION CONTROL PLANS

Summary

When new-vehicle emission standards and stationary-source control are fully implemented, twenty-seven Air Quality Control Regions (AQCR) are still expected to exceed the oxidant and carbon monoxide air quality standards of 1975. To meet the air quality standards, these AQCR's will be required to implement Transportation Control Plans (TCP). The aim of the TCP's is to reduce total emissions of in-use vehicles by implementing either or both of the following strategies to control total emissions from in-use vehicles:

- Measures that reduce emissions per vehicle mile of travel
- Measures that reduce total vehicle miles travelled (VMT).

The first strategy includes the application of retrofit control systems, inspection and maintenance of vehicles, and service station vapor controls. The second strategy contains mass transit improvements, carpool programs, and other methods that will reduce the use of low-occupancy automobiles.

A detailed discussion of measures contained in the TCP's is given in the following paragraphs. Costs for implementing the inspection and maintenance programs, installation of retrofit devices, and service station vapor control systems are estimated for each AQCR for the period 1976 to 1985 inclusive. The costs to the vehicle owners of implementing these measures are estimated to be $344 million in 1976, $441 million in 1977, and thereafter remaining relatively constant through 1985. However, a net benefit results by taking into account the fuel savings that are expected to result from tune-ups required by the inspection and maintenance strategies. Hence, the cumulative benefit for the period 1976-85 is estimated to be about $540 million (see Table 2-13). Approximately $664 million will be spent for capital investment over the decade and a little over $3 billion will go to operation and maintenance of the program (see Table 2-14). To maintain maximum clarity and usability, it was decided not to convert the U.S. units of measure contained in this section to metric equivalents.

Introduction

The Clean Air Act Amendments of 1970 (hereafter referred to as the Act) directed EPA to set national primary and secondary ambient air quality standards. The primary standards must be established so that their attainment and maintenance will protect the public health with an adequate margin of safety. The secondary standards will protect the public welfare from any known or anticipated adverse effects associated with the presence of air pollutants. In 1971, national ambient air quality standards were established for six pollutants, including the four primary pollutants associated with motor vehicles: carbon monoxide, nitrogen dioxide, photochemical oxidant, and hydrocarbons. Hydrocarbons are reactants in the formation of oxidants, and they have no known health effects at ambient concentrations. The primary and secondary standards for these pollutants are identical and are shown in Table 2-1.

Table 2-1.
National Primary and Secondary Ambient Air Quality Standards

Pollutant	Air Quality Standard[1] (ppm)	Averaging Time
Hydrocarbons	0.24 or 9.00	3 hours or 8 hours
Carbon Monoxide	35.00	1 hour
Nitrogen Dioxide	0.05	Annual
Photochemical Oxidant	0.08	1 hour

[1] Primary and secondary standards for these pollutants are identical. Standards are not to be exceeded more than once a year.

Source: Reference 1.

The standards for the motor-vehicle-related pollutants have been exceeded in a number of major urban areas. From the State Implementation Plans (SIP) submitted to EPA by the states in February 1972, it was found that of the 247 AQCR's in the United States, 54 regions exceeded the air quality standard for oxidants, 29 exceeded the carbon monoxide standard, and 2 exceeded the nitrogen dioxide standard. In total, sixty-six AQCR's, representing roughly 60 percent of the nation's population, exceeded one or more of these standards.

The Act established three principal approaches to achieving the air quality standards:

- Emissions standards for new automobiles
- Emissions standards for stationary sources (power plants, industrial sources, and general area sources)
- In-use vehicle controls.

EPA is authorized to promulgate and enforce emissions standards for new automobiles, trucks, and motorcycles. EPA has used this authority to establish increasingly stringent emissions standards for cars and initial standards for trucks. More stringent truck standards as well as motorcycle emissions standards are now under development.[2] The Energy Supply and Environmental Coordination Act of 1974 extended the 1975 and 1976 deadlines of the Act for two years.

Reductions in pollutant concentrations resulting from the implementation of new-vehicle emissions standards and stationary-source controls were projected to significantly reduce the number of AQCR's exceeding the oxidant or carbon monoxide air quality standards. These include approximately 40 percent of the nation's population. Table 2-2 presents a list of these AQCR's together with the ambient concentrations for carbon monoxide and photochemical oxidants measured through 1972. Having controlled the emissions from stationary sources and new vehicles to the extent possible, those states containing the AQCR's that are still projected to exceed the air quality standards will be required to implement transportation control plans, i.e., control of in-use vehicles, to meet the requirements of the Act. This section describes the TCP's to be implemented in those states containing the AQCR's listed in Table 2-2, and it includes the estimated costs to the nation.

Table 2-2.
1971-1972 Air Quality Levels in Regions Projected to Exceed Primary Ambient Air Quality Standards in 1975

Carbon Monoxide - 8 Hour Average (ppm)

10-15	16-20	21-24	25-35	36-42
Indianapolis	San Diego	Sacramento	Fairbanks	Los Angeles
Minneapolis-St. Paul	San Francisco	Baltimore	Phoenix-Tucson	New York City
	San Joaquin	Boston	Denver	
	District of Columbia	Springfield	Philadelphia	
	Seattle	Portland		
	Spokane	Pittsburgh		
	Chicago	Salt Lake City		

Oxidant - 1 Hour Average (ppm)

0.10-0.15	0.16-0.20	0.21-0.30	0.31-0.40	Greater than 0.40
Phoenix-Tucson	Denver	Sacramento	San Diego	Los Angeles
Philadelphia	District of Columbia	San Joaquin	San Francisco	
Pittsburgh	New York City	Baltimore	Houston-Galveston	
Dallas-Ft. Worth		Boston		
San Antonio				
Indianapolis				
Rochester				
Cincinnati				
Portland				
Seattle				
Springfield				

Source: Reference 2, p. 22.

Overall Strategies

TCP's make use of either or both of the following strategies to control total emissions from in-use vehicles:

- Measures that reduce emissions per vehicle mile of travel
- Measures that reduce total vehicle miles travelled (VMT).

The first strategy includes the inspection and maintenance of vehicles in use and the application of retrofit control systems. The second strategy includes mass transit improvements, carpool programs, and other methods that will reduce the total use of automobiles. TCP's mainly pursue the above strategies with respect to automobile travel. The goals are to reduce emissions per vehicle mile and/or to reduce VMT for automobiles. Although motor vehicles are not the only source of hydrocarbons, carbon monoxide and nitrogen oxide emissions, Table 2-3 clearly indicates the significance of automotive emissions.

Table 2-3.
Mix of Emission Sources in Urban Areas - 1971

	Percent of Total Emissions		
Pollutants	Automobiles	Trucks, Buses & Motor-cycles	Stationary Sources
Carbon Monoxide	77-87	8-10	3-15
Hydrocarbons	50-65	5-10	25-45
Nitrogen Oxides	40-50	8-13	37-52

Source: Reference 3, p. III-23.

Measures that Reduce Emissions Per Vehicle Miles

INSPECTION AND MAINTENANCE PROGRAMS

The term "inspection and maintenance" covers a variety of strategies for reducing air pollutant emissions from light-duty motor vehicles that are currently in use by establishing procedures that will ensure proper maintenance of vehicles. Emissions from most vehicles tend to increase with use until the vehicle on the road is properly tuned. Thus, most vehicles on the road are emitting more than they were designed to emit or more than they would be emitting after a tune-up. The inspection and maintenance programs will systematically reduce the emissions from an automobile population.

Most of the inspection and maintenance programs have two distinct phases:

- An inspection phase, in which motorists are required to periodically present their vehicles for examination

- A maintenance phase, in which vehicles that fail the examination must be tuned up to bring them into compliance.

Three classifications cover the major alternative approaches in an inspection and maintenance program[4].

- Exhaust emissions inspection
- Engine parameter inspection
- Mandatory maintenance.

The exhaust emissions inspection will be the only one discussed because it is the only approach that is being used at present in those states that have initiated the program.

Exhaust Emissions Inspection. This inspection technique involves sampling the exhaust gases from the examined vehicle and passing the samples through suitable analytical instrumentation to measure the quantities of air polluting compounds they contain. If the concentration of each compound falls below the applicable emissions standards, the venicle passes the examination. If the concentration of any pollutant is above the standard, the vehicle fails. If a vehicle fails the test, it must then be adjusted or repaired to bring the emissions into compliance. Following the maintenance, the vehicle would normally be resubmitted for an emission test to ensure that it is in compliance.

There are two types of vehicle operating modes that can be used in an emissions inspection test. In an idle mode test, emissions from the vehicle are measured using a tail-pipe concentration while the vehicle is running in neutral. In a loaded mode test, the emissions are measured while the vehicle is running in gear on a treadmill-like device called a dynamometer. When operating in this test mode, the vehicle can be drive in several conditions, such as acceleration, cruise, deceleration, and idle. A driving cycle composed of a series of different driving modes can more accurately represent actual driving conditions. Thus, emissions measurements taken in a loaded mode test are usually more representative of actual driving emissions than the measurements taken in an idle test[5]. However, due to its more sophisticated equipment, the need for larger testing and facility areas, and a longer testing time per vehicle, the cost of a loaded mode program is higher than the cost of an idle mode program for a given vehicle population.

The choice of which inspection and maintenance program to implement is a function of several factors, including the desired emissions reduction, ownership and operation of the inspection stations (public or private), and the relationship of the inspection and maintenance program with existing vehicle safety inspection programs.

In general, it is desirable to incorporate the inspection and maintenance program with a vehicle safety inspection program when one exists. If this approach is taken, the manner in which the safety program is operated will have an effect on the type of inspection and maintenance program that is chosen. Of the thirty-two states, including the District of Columbia, which have safety programs, only three states have publicly owned and operated stations. Safety programs in the remaining states are operated through private garages and service stations. Loaded mode inspection and maintenance programs could be incorporated into a state-owned safety program, but it would be difficult to incorporate a loaded mode test program into a state-licensed safety program because of the high cost of the test equipment. Therefore, in most cases idle mode tests could be incorporated with state-licensed stations and loaded mode tests with state-owned safety inspection stations. If a loaded mode test is required in a state with a state-licensed safety inspection program, it is most likely that a separate state-operated emission test program would have to be started.

Twenty-four areas are required to have some form of inspection and maintenance program within the next two years under the TCP's which have been approved or promulgated. There are mandatory safety inspections in 13 of these TCP areas. The plans specifically call for 20 idle mode and 7 loaded mode programs. The number of plans do not add to 24 because some AQCR's will include both idle mode and a loaded mode or privately and publicly owned inspection facilities as shown in Table 2-7.

The expected emission reductions from an inspection and maintenance program are a function of the mode type, the frequency of the inspection, and the percentage of the vehicle population that fail the inspection. In general, inspection programs will be conducted on an annual cycle. Reductions in hydrocarbons and carbon monoxide emissions, but not nitrogen oxide emissions, can be expected. Table 2-4 provides expected emission reductions for the idle and loaded mode programs for various failure rates.

Table 2-4.
Inspection and Maintenance Emission Reduction Effectiveness

Hydrocarbon Emission Reductions
(Percentage of Emissions from All Vehicles Inspected)

Failure Rate

(Percentage of Vehicles Tested)

Mode Type	10	20	30	40	50
Idle	6	8	10	11	11
Loaded	8	11	13	14	15

Carbon Monoxide Emission Reductions
(Percentage of Emissions from All Vehicles Inspected)

Failure Rate

(Percentage of Vehicles Tested)

Mode Type	10	20	30	40	50
Idle	3	6	8	9	10
Loaded	4	7	9	11	12

The failure rate is only a convenient shorthand way of referring to the stringency of the emission standards. Actually, the state will adopt specific emission standards which each vehicle will be required to meet. When the emission standards are compared to the distribution of emissions for the total vehicle population, the percentage of vehicles that are above the emission standard can be determined. The resultant percentage represents those vehicles that will fail the inspection and is termed the failure rate. Thus, the more stringent the standard, the higher the failure rate. Since the emissions distribution for the vehicle population can change from year to year, the failure rate would also vary accordingly.

Costs will vary positively with the failure rate. Vehicles that fail the test must receive corrective maintenance and be retested. Program capacity must therefore be based not only on the projected failure rate, but also on the rate of retesting. Increased vehicle capacity must be met by adding additional testing facilities and/or increasing the hours of operation.

RETROFIT CONTROL PROGRAMS

A retrofit approach can be defined as the addition of any device or system and/or any modification or adjustment on a motor vehicle after its initial manufacture to achieve a reduction in emissions[6]. Retrofit programs go beyond the attempt made by inspection and maintenance programs to keep in-use vehicles at minimum emission levels consistent with their type and original design. The only way to reduce the rate of emissions from vehicles in-use further than the level attained through inspection and maintenance is to require retrofits. The objective of a retrofit program is to reduce the emission levels of an in-use vehicle below its "well-maintained" levels through the addition of a device or system and/or a modification or adjustment after its initial manufacture.

Normally, a retrofit program will not be planned unless additional stationary-source controls, inspection and maintenance, and some modest VMT reduction measures are also implemented because retrofit devices alone are not enough to meet the national air quality standards. This is principally because of the high cost of retrofit devices and the relatively short life-span of their effectiveness, i.e., as older vehicles leave the population, so do the retrofit devices, and the effect of the low emitting new vehicles becomes more predominant. All retrofit programs must embody several important factors to be effective. These factors include:

1. Choosing retrofit system that is most closely matched to the particular pollutant problem in the area, since different retrofit systems provide different emission reductions for the three pollutants;
2. Assuring that a sufficient number of devices and trained installation personnel will be available;

3. Incorporating a testing requirement at the time of installation; and

4. Providing for annual inspection and maintenance of retrofitted vehicles to assure proper operation in subsequent years.

The two retrofit programs currently under consideration for wide-spread implementation are:

- Vacuum Spark Advance Disconnect (VSAD)

- Air Bleed to Intake Manifold

In addition, a high altitude modification to the air bleed retrofits has been under consideration for Denver and Salt Lake City. This modification involves timing and carburetor changes on the air bleed. Preliminary test runs in Denver by EPA showed that the high altitude modification would not significantly reduce emission levels. Instead, an air bleed system with exhaust gas recirculation appears to be more desirable

The characteristics of the two main types of retrofit systems, including a description of the system, its applicability, the expected emission reductions from its implementation, and other considerations are discussed below.

Vacuum Spark Advance Disconnect (VSAD). Two basic engine modifications employed by motor vehicle manufacturers in meeting Federal exhaust emission standards have been the leaning of air/fuel ratios and the modification of ignition(spark) timing. The modification of these parameters in precontrolled (pre-1968) vehicles will reduce carbon monoxide emissions by 9 percent, hydrocarbon emissions by 25 percent, and nitrogen oxide emissions by 23 percent, resulting in a fuel penalty of up to 2 percent[7]. Durability data developed by General Motors over 25,000 miles without maintenance show no deterioration in the reduction of hydrocarbons and nitrogen oxides over time, but do show approximately a 20 percent deterioration for carbon monoxide. Because the 1968 model and newer vehicles have utilized these modifications to some extent to meet Federal emission standards, this retrofit technique is considered to be applicable primarily to precontrolled vehicles, but not to approximately 10 percent of those precontrolled vehicles which do not employ vacuum spark advance.

Air Bleed to Intake Manifold. Many devices have been designed to introduce excess air in the fuel mixture prior to combustion by one means or another. The effect reduces hydrocarbon and carbon monoxide with possibly some small increase in nitrogen oxide emissions. The reductions achieved vary directly with the amount of air allowed into the intake system. This technique is applicable to some extent to all light-duty vehicles through the 1971 model year, but because of the relatively lean air/fuel ratios on most controlled vehicles, the technique is primarily applicable to precontrolled vehicles (pre-1968).

Tests conducted on this system for EPA indicate an expected reduction of 23 percent for hydrocarbons and 50 percent for carbon monoxide emissions with a fuel benefit up to 4 percent[7]. No significant effect on nitrogen oxide emissions has been observed. Durability data on the system are not adequate for judging the performance of this control technique over an extended time frame.

SERVICE STATION VAPOR CONTROLS

Although the hydrocarbon vapors emitted to the atmosphere from service stations cannot be considered in-use vehicle exhaust emissions, the relationship between these vapor losses and vehicle use is so directly related that their control can legitimately be thought of as a transportation control.

Gasoline is a volatile liquid that tends to evaporate at ordinary ambient temperatures. The vapors thus created become a significant source of hydrocarbon emissions and, consequently, of photochemical oxidants. In some metropolitan areas these vapors contribute as much as 15 percent of the total hydrocarbon emissions[8]. Gasoline may evaporate at any of the points at which it is stored or handled and enter the atmosphere either through "breathing" from vents in the storage tanks (at the bulk terminal, in tanker trucks, at the service station, or in the automobile tank) or during the process of transferring from or refilling of each of these tanks.

The California Air Resources Board estimates that 23 pounds of hydrocarbons are emitted for each thousand gallons of motor fuel sold at stations in an uncontrolled situation; 11 pounds from transferring fuel from transport to station storage, 11 pounds in moving fuel from storage to a car tank; and 1 pound in "breathing" losses from underground storage. A study by the Standard Oil of California reports similar results[9]. The average service station sells approximately 25,000 gallons of gasoline per month which results in hydrocarbon emissions of 575 pounds per month.

EPA estimates such emissions to be around 400 pounds per station per month[2,10,11]. By 1975, uncontrolled vapor losses of this magnitude will make the service station as significant a source of hydrocarbon emissions as some of the vehicles it serves. When translated into grams per mile, the hydrocarbon emissions from service stations exceed the 1977 new car hydrocarbon standards[2].

Vapor Control Stages and Techniques. Service station vapor losses result primarily from tank truck unloading (Stage I) and vehicle fueling (Stage II). The basic measures to reduce either the evaporation or subsequent emission of vapors to the atmosphere in Stage I include the following:

1. Floating roofs on large storage tanks. These devices reduce the airspace above the liquid where evaporation may occur.

2. Submerged filling of tanks. This allows new gasoline to flow into the liquid already in the tank, eliminating splashing which would otherwise increase the amount of vapor.

3. Restrictions on vent pipes on the stationary storage tanks. This technique limits the amount of "breathing" which occurs through the vents.

4. Use of vapor return lines. This method allows vapors in the tank being filled to be transferred back into the tank from which the gasoline is being taken.

5. Secondary recovery systems. Carbon absorption or refrigeration-condensation systems are used to neutralize or reprocess the vapors that otherwise might be emitted.

Of these control techniques, submerged tank fill is required for any new station storage container (in most regions) with a capacity greater than 250 gallons, and any existing container over 2,000 gallons. In addition, displaced vapors must be either transferred back to the delivery vessel through a vapor-tight return line, or they must be processed on the location by a refrigeration-condensation system or other appropriate system designed to recover or eliminate at least 90 percent (by weight) of the organic compounds in the displaced vapors. If the vapors are transferred to the delivery vessel, such as a tanker truck, the tanker must be refilled at facilities equipped with processing systems (such as refrigeration-condensation, carbon absorption, etc.) which can recover at least 90 percent of the organic compounds in the vapors.

On February 8, 1974, sources were required to submit control plans to EPA for Stage I vapor recovery by June 1, 1974[12]. EPA has been unable to approve many control plans submitted because sources failed to include sufficient information or technical justification. Guidelines for Stage I vapor recovery are being prepared by EPA and will be made available to sources in the very near future. Therefore, EPA postponed the date for sources to enter and sign contracts for control systems and the date for sources to initiate on-site construction or installation of control equipment.

Stage II controls (recovery of vapors displaced during refueling of automobiles) could theoretically make use of any of the Stage I control techniques described above. However, submerged fill, collapsible bladders (the small scale equivalent of a floating roof), and carbon canisters to absorb all vapors during fueling would require redesign of present automobiles and are not being considered by EPA for Stage II controls. Restrictions on vent pipes (often including small carbon canisters on the vehicles) were introduced to comply with the Federal Motor Vehicle Control Program in the 1970 model year, although pre-1970 vehicles have vent pipes open to the atmosphere. The remaining control technique is the collection of vapors displaced during fueling, and the subsequent processing of the vapors through a vapor return line to the service station storage tank.

Essentially two techniques have been developed for the collection of vapors displaced from automobile tanks through vapor return lines: simple displacement or "balance" and vacuum-assist. After the vapors are collected, they can be recovered or reprocessed either at the service station or at the bulk terminal. Thus, recovery systems, such as carbon absorption, refrigeration-condensation, or incineration, can be installed either at the service station or at the bulk terminal. A substantial controversy has recently arisen over the effectiveness of simple displacement systems and the reliability of vacuum-assist systems. Comment period on the regulations was reopened, and EPA has postponed the requirement for submission of control plans from June 1, 1974, to December 1, 1976, with the final compliance to be achieved no later than May 31, 1977.

Measures that Reduce Total Vehicle Miles Travelled

THE NEED FOR VMT REDUCTIONS

In the previous section, three measures to reduce emissions per vehicle mile (in-use controls) were described. In this section, a brief description of measures which reduce VMT is presented.

The potential air quality benefits of in-use vehicle controls is shown in Table 2-5. The table shows that if in-use vehicle and stationary-source controls are fully implemented by 1977, at least eight regions in 1980 and five regions in 1985 are expected to fail to comply with oxidant and/or carbon monoxide standards. Therefore, if further control of motor vehicle emissions is necessary, reductions in automobile use are required to comply with the air quality standards.

Table 2-5.
Number of AQCR's Failing to Comply with Oxidant and/or Carbon Monoxide Standard in Indicated Year[1]

	Calendar Year		
Conditions	1977	1980	1985
Without In-use Vehicle Controls[2]	21-24	12-14	9-10
With In-use Vehicle Controls[3]	12-17	8-10	5-10

[1] Ranges reflect uncertainty in degree of stationary-source control that will be achieved. Air quality projections are based on linear rollback for carbon monoxide and Reference 13 for oxidant. Analysis excludes New York, Denver, and Fairbanks.

[2] Control strategy consists of stationary-source controls and Federal Motor Vehicle Emission Control Plan (FMVECP).

[3] Control strategy consists of stationary-source controls, FMVECP, inspection and maintenance, retrofit (including catalyst retrofit), and vapor controls.

Source: Reference 2.

In any particular AQCR, the adequacy of transportation emission control strategies for achieving the national ambient air quality standards will depend on the severity of the air pollution problem within the region, the relative contribution of mobile and stationary emission sources, ard the relative growth rates of these sources.

Thus, the extent of automobile use reductions will vary substantially among the AQCR's in which they are needed. Table 2-6 displays the distribution of automobile use reductions (measured as vehicle miles of travel) necessary to achieve nationwide compliance with the ambient air quality standards in 1977 and 1985; the projected VMT reductions needed in 1985 and beyond are highly uncertain. This is due to their extreme sensitivity to a number of parameters used in the projection calculation; namely, the relative contributions of different emission sources, the growth rates of these sources, and the extent of stationary-source control achievable. Accordingly, a broad range of the number of cities in each of two categories is shown; one category shows the number of cities needing between zero and 25 percent VMT reductions, the other shows the number of cities requiring VMT reductions greater than 25 percent. The actual reductions needed by the cities in this latter category will depend primarily upon the degree of stationary-source control that can be achieved in 1985.

Table 2-6.
Number of AQCR's Requiring Automobile Use Reduction to Achieve Compliance with Oxidant and/or Carbon Monoxide Standards[1]

	Automobile Use Reduction			
Calendar Year	Less than 10%	10%-30%	30%-50%	50% or more
1977	8	5	4	4
1985[2]	0-25% 6-8	25% or more 4-6		

[1] The VMT reductions estimated for each AQCR are based on the additional control of motor vehicle emissions required, assuming the regional I/M and retrofit programs for in-use vehicles are fully implemented by 1977. Air quality projections are based on linear rollback for carbon monoxide and Reference 13 for oxidant. The number of AQCR's whose current transportation control plans include auto use reductions exceeds the number used here because some plans have substituted VMT reduction for retrofit. Auto use reductions are expressed as percent reductions in VMT.

[2] Ranges reflect uncertainty in the degree of stationary-source control that will be achieved and the future growth in automobile use. Source: Reference 2.

The automobile use projections, upon which the analyses presented in Table 2-6 are based, reflect trends as of 1973. Thus, nationwide automobile use (VMT) is projected to be about 55 percent greater in 1985 than in 1972. This projection assumes an increasing number of vehicles per person and an increasing annual mileage per vehicle. If the recent downward trend in automobile sales per person continues for a number of years so that the number of vehicles per person and the annual mileage per vehicle remains constant through 1985, automobile use would be only about 18 percent above current levels. This represents a VMT reduction of 25 percent from the projected baseline assumed for Table 2-6 which reduces significantly the number of AQCR's requiring VMT reductions to achieve compliance with the standards.

STRATEGIES TO REDUCE VMT

There are generally two strategies to achieve VMT reductions:

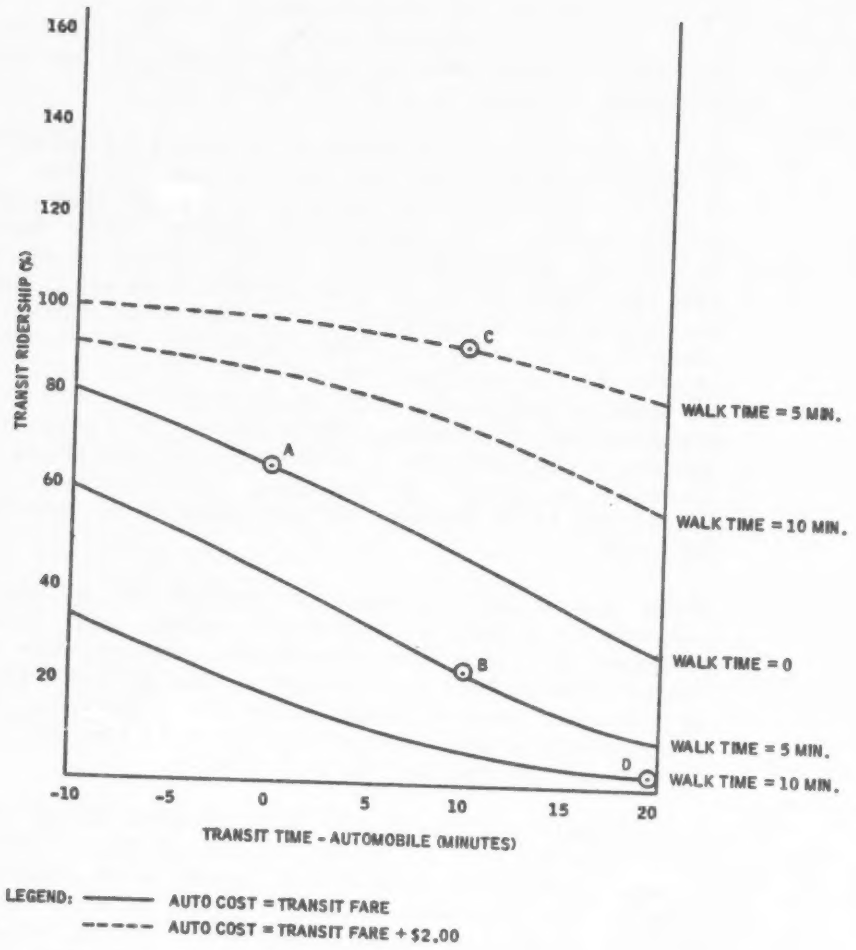
- Improvements in transit systems to encourage automobile drivers to reduce trips.
- Incentives to increase the number of passengers per automobile.

Transit Improvements. To attract significant numbers of automobile drivers out of their cars, a transit system must at least satisfy three conditions:

- It must have enough vehicles to carry the new riders.
- It must provide service whose quality is comparable or superior to that of the automobile. The most important component of service quality is travel time.
- Its cost to the rider must be attractive relative to the cost of operating an automobile.

An example of the relationship between travel time, cost, and transit ridership for work trips is illustrated in Figure 2-1, which is based upon the results of a study of travel behavior in Pittsburgh, Pennsylvania[14]. The variables included in the figure are the time required to walk to and from the transit stop, the difference between automobile and transit travel times, the difference between automobile and transit costs, and the percentage of work trips taking place by transit. The importance of the time and cost variables in determining transit ridership can be illustrated by considering the case where transit and automobile travel times and costs are equal (Point A of Figure 2-1). The figures indicate that 66 percent of work trips would take place by transit. In constrast, average work-trip transit ridership in the United States is currently less than 15 percent.

Figure 2-1.
Dependence of Work-Trip Transit Ridership on Service Quality



In practice, it is unlikely that a transit system can offer widespread service which is as fast as that of the automobile. A more realistic example of a high-quality transit system is illustrated by Point B of Figure 2-1. Here, the walk time is five minutes, transit travel time exceeds automobile travel time by 10 minutes, and the transit fare and automobile cost are equal; transit ridership is 21 percent. If the walk and travel times remain unchanged and the automobile costs $2.00 per work trip more than transit owing to free transit, parking charges, or other reasons, transit ridership for work trips increases to about 90 percent (Point C).

The reductions in the combined emissions of automobiles and transit vehicles thus achieved depend on the kinds of transit vehicles used, and the design and operation of the transit system. For example, if diesel buses meeting the California 1975 heavy-duty diesel emission standards are used and these buses carry an average load of 20 passengers, the reductions in combined bus and automobile emissions are roughly 30 percent for carbon monoxide and hydrocarbons and 15 percent for nitrogen oxides in 1977. In 1985, when automobile emissions will be less than in 1977, the carbon monoxide and hydrocarbon reductions are 20 percent and 25 percent, respectively. However, nitrogen oxide emissions increase by about 20 percent; this increase would be eliminated if an average bus occupancy of 30 passengers were achieved.

These quantitative results are approximate because of their reliance on a single behavioral study and rather crude measures of trip characteristics. However, the conclusion that a high-quality transit system can attract high levels of ridership is also supported by the experience of existing high-quality transit operations, such as the Shirley Highway Express in the Washington, D.C. area[15].

Most transit systems in the United States do not provide the high-quality service needed to attract high ridership. For example, nearly 50 percent of urban area residences are located three or more blocks from the nearest transit stop. Transit routes are heavily downtown-oriented, but only about 10 percent of the trips go downtown. Transit trips take nearly twice as long as automobile trips. Moreover, subsidized free or reduced rate parking confers a cost advantage on the automobile. Transit service of this quality is illustrated by Point D of Figure 2-1, indicating a ridership of 4 percent.

Carpools. Average automobile occupancy in the United States is about two persons per car. Average occupancy for work trips is about 1.4 persons per car[16]. Since most cars are capable of carrying at least four persons, there is considerable room for reducing automobile use and emissions through carpooling. The principal obstacle to carpooling is that carpools are highly restrictive in terms of the service offered. Carpoolers must have trip origins and destinations that are close to one another, must travel at the same time, and, to minimize the problems of locating carpool partners, must make trips that are repetitive from day-to-day. As a result, the greatest potential for increased carpool use is in connection with peak-period work trips. These trips are responsible for about 25 percent of urban area automobile emissions[17].

The present automobile low occupancy rates for work trips indicate that substantial carpooling will not take place unless certain measures are implemented to encourage it. The limited experience to date with carpool programs has provided indications of the effectiveness of two possible approaches to encouraging carpools:

- Preferential treatment for carpools on streets and freeways.

- Parking restrictions combined with locator systems.

Preferential treatment for carpools has been observed to increase peak-period automobile occupancies by 10 to 30 percent[18]. Locator systems combined with parking restrictions appear capable of doubling occupancies for downtown peak-period work trips to suburban locations[19]. If these preliminary indications are confirmed by future experience, programs to encourage carpooling should be capable of reducing total urban area automobile emissions by 5 to 10 percent.

Carpooling and transit systems appear to be competitive, not complementary, approaches to reducing automobile use. Both approaches operate most easily in connection with peak-period work trips to high density areas, and transit system improvements tend to attract passengers from their carpools. It is therefore unlikely that the effects of high-quality transit systems and carpooling on automobile use will be additive. For example, if transit system improvements alone can achieve a 15 percent reduction in automobile use and carpooling alone can achieve a 10 percent reduction, the automobile use reduction obtained from implementing both approaches together is likely to be greater than 15 percent but less than 25 percent.

TRANSPORTATION CONTROL MEASURES TO REDUCE VMT

In this section, specific VMT reduction measures considered by the states, localities, and EPA in developing TCP's will be briefly explained.

Bus and Carpool Priority Treatment. Priority treatment for buses and carpools consists of allocating highway facilities preferentially to these vehicles for the purpose of increasing their average speeds. The usefulness of bus priority treatment in attracting automobile drivers to use the transit is dependent on the quality of the transit system or subsystem that uses priority treatment. Hence, in areas where bus priority treatment is included in a TCP, the measure is a part of an integrated transit improvement program. For example, in the Washington, D.C. area, priority treatment is used in combination with bus fleet expansion, the addition of new transit routes, and improved bus scheduling.

Carpooling Programs. Many TCP's include measures that provide computerized carpool matching programs and preferential carpool treatment programs. The matching programs provide for the formation of carpools, and the preferential treatment programs provide incentives, such as free parking, to encourage carpools.

Computerized carpool locator programs have been established in cities such as Washington, D.C., Boston, Massachusetts, Knoxville, Tennesse, and Omaha, Nebraska.

Employer Transit Incentive Regulations. Employer incentive regulations applicable in several metropolitan areas require major employers to implement measures that encourage the use of carpools and mass transit, while at the same time discouraging the use of single-passenger automobiles for work-related commuting. Under this approach, the employer has the flexibility to develop his own plan to minimize the impact of his facility on the area's VMT. The concept is based on already existing programs that have been developed by employers to discourage energy-inefficient commuting habits. In addition, many employers have voluntarily started such programs to avoid the acquisition of land for additional parking facilities. Companies, such as Minnesota Mining and Manufacturing and Aerospace Corporation of El Segundo, California, have already illustrated the effectiveness of this approach in reducing commuter automobile usage.

Parking Programs. Parking management programs are used in several TCP's to complement the improvement of mass transportation and carpooling alternatives. The transportation plans include two general types of parking regulations: on-street parking controls and parking management programs. The on-street parking controls are similar to common regulations in various cities to prevent congestion and to discourage commuter parking on public streets.

The States are encouraged to develop their own area-wide parking facility plans. These plans should focus on the interrelationship of transportation alternatives and new parking facilities. The plans should set forth the manner in which the location, operation, and increase in the number of parking-related facilities would be kept consistent with the air quality needs throughout the area. The plans could also ensure that the new facilities complemented rather than competed with existing and developing transit facilities. Several areas, such as San Diego, Los Angeles, Portland, and Seattle, have begun such plans for parking restrictions as a traffic control approach.

Transit Expansion and Development. The improvement and expansion of mass transit facilities is one of the key elements for the success of transportation plans. Bus fleet expansion will allow service to be upgraded in several major respects:

- Existing routes can offer more frequent service.

- New routes can be established to allow more people the opportunity of transit.

- Older, uncomfortable vehicles can be replaced with smoother riding, air-conditioned vehicles.

Within the last two years, many areas have established programs to improve and upgrade existing transit systems. Therefore, in the near future many areas will begin to offer the type of alternative transit that is required to help achieve the required VMT reductions. An example of the type of improvement which can effect a reduction in VMT is the Seattle "Magic Carpet" program. City-wide fare reductions along with free fares within the CBD were associated with a fleet expansion and exclusive bus lanes. The increased ridership will help Seattle achieve the VMT reductions necessary to meet the National Ambient Air Quality Standards.

Sufficient Federal funding is necessary if areas are to expand transit systems to the level necessary to provide assistance in achieving the VMT reduction goals contained in the plans. EPA has been working with DOT to assure the availability of such funding. In addition, states and localities must be willing to increase their support for mass transit. Ideas such as using sales tax revenues for capital and operating expenses and therefore stabilizing fares have been successfully implemented in Atlanta, Georgia. Other areas must continue to provide the necessary local commitment if expanded mass transit is to become a reality.

Parking Surcharge and Parking Fees. The use of surcharges on commercial rates for parking both discourages non-carpool commuting and provides a source of financing for transit improvements. The measure can help bring about a significant change in urban driving habits with a minimum of social disruption if the fees are properly formulated and integrated with transit improvements. The program offers a wide latitude of individual choice to the driver. Those whose needs or preferences are strongly in favor of using the single passenger automobile may continue to do so, although at a somewhat higher cost; those who can easily adapt to other modes of transit or a carpool will have the incentive to take such action. The Energy Supply and Environmental Control Coordination Act of June 1974 (P.L. 93-319) forbids the EPA from promulgating surcharges.

Gasoline Supply Limitations. Gasoline supply limitations are, at least in theory, one of the most effective methods of reducing VMT. At the time the TCP's were first proposed, gasoline supply limitations were considered to be included in several plans. Two types of regulations were proposed:

1. A gasoline supply lid would have become effective during 1974 or 1975, which would have limited the quantity of gasoline sold in an area to fiscal 1973 levels.

2. A regulation, which would be implemented on May 31, 1977, would reduce an area's gasoline supply and thus VMT to the extent necessary to achieve the ambient air quality standards.

The gasoline supply lid was dropped as a primary control measure by EPA at the time the plans were finally promulgated. The determination not to include gasoline supply lids as a "reasonably attainable" alternative was based upon the comments received during the public hearings held on each plan and the Agency's evaluation of the feasibility of implementing and administering an effective program. Moreover, possibilities of evasion, the likelihood of noncompliance, and the difficulty of enforcement appeared too great to make this measure praticable.

However, the gasoline supply reduction to be implemented on May 31, 1977, has been retained in plans for several areas. In these areas, this measure was included as a final resort measure to fulfill the statutory requirement that a plan must achieve the ambient air quality standards by 1977. In each of these areas, even with additional stationary-source controls, inspection and maintenance programs, reasonable VMT control measures, and retrofit strategies, additional VMT reductions were necessary to demonstrate attainment of the standards. As the EPA Administrator has stated on several occasions, this measure has been included in these plans to meet the technical requirements of the law, and the EPA does not intend to implement this measure unless it is leagally required to do so. EPA has submitted a proposed amendment to the Clean Air Act which would allow additional flexibility in these heavily impacted areas.

ADDITIONAL VMT REDUCTION MEASURES

Several other measures were considered and accepted or rejected for use in TCP's. Measures used by the states or EPA to a limited extent include bicycle lane programs, vehicle-free zones, selective vehicle exclusion strategies, and gasoline truck delivery bans. Of these, the first two measures are being implemented on a limited basis, such as the bicycle lane program now underway in Denver, Colorado, and the vehicle-free zones in Springfield, Massachusetts, the Camden-Trenton area of New Jersey, and Salt Lake City, Utah. The last two measures (selective vehicle exclusion and gasoline truck delivery bans) were considered for implementation but were rejected.

Costs of Transportation Control Plans

This section estimates the aggregate costs to the motor vehicle owners of implementing TCP's. In order to estimate aggregate costs for the period 1976-85, costs of implementing various transportation control measures at each AQCR have been computed. Table 2-7 presents the list of AQCR's which will implement specific measures that will reduce emissions per VMT; the table also describes the geographic and model year coverage of each measure.

Table 2-7.
List of AQCR's Which Will Implement Measures to Reduce Emissions Per Vehicle Mile of Travel

AQCR	I/M			Retrofit				-SSVC	
				VSAD		Air Bleed			
	Test Type	Ownership	Area Covered	Vehicle Year	Area Covered	Vehicle Year	Area Covered	Stages	Area Covered
Boston	Idle	Private	AQCR	Pre-68	AQCR	1968-71	AQCR	I & II	AQCR
Springfield	Idle	Public	Springfield SMSA						
NY-NJ-Conn.	Idle	Public	N.J. part of AQCR			Pre-71	N.J. part of AQCR	I & II	N.J. part of AQCR
	Loaded	Public	N.Y. SMSA						
Philadelphia	Idle	Private	Penn. part of AQCR			Pre-68	Penn. part of Phila. SMSA		
	Idle	Public	N.J. part of AQCR			Pre-71	N.J. part of AQCR	I & II	N.J. part of AQCR
Southwest Penn.	Idle	Private	AQCR					I	Allegheny County
Baltimore	Idle	Private	AQCR	Pre-68	AQCR	1968-71	AQCR	I & II	AQCR
Natl. Capitol	Idle	Public	Va. part of AQCR	Pre-68	AQCR			I & II	AQCR
	Idle	Private	D.C. & MD part of AQCR						
Chicago	Idle	Public	Cook Cty. inc. Chicago						
Indianapolis	Idle	Private	Marion Co.	Pre-68		Marion Co.		I	Marion County
Cincinnati	Idle	Public	Hamilton County						
San Antonio	Idle	Private	Note 1					I & II	San Antonio County
Houston - Galveston	Idle	Private	AQCR	Pre-68	AQCR			I & II	AQCR
Denver	Idle	Public	AQCR			Pre-68	AQCR	I & II	AQCR
Phoenix - Tucson	Loaded	Public	AQCR			Pre-68	Phoenix & Tucson SMSA's		
Wasatch Front	Idle	Public	Note 2			Pre-68	AQCR excluding Tooele Co.		
Los Angeles	Loaded	Public	AQCR	1955-65	AQCR			I & II	AQCR
San Francisco	Loaded	Public	AQCR	1955-65	AQCR			I & II	AQCR
San Diego	Loaded	Public	AQCR	1955-65	AQCR			I & II	AQCR

NOTES: 1 San Antonio SMSA and Kendall, Medina, Wilson, Atascosa, Comal Counties.
2 Ogden, Salt Lake City, Provo- Orem SMSA's.
3 Boston and Houston - Galveston AQCR's have recently cancelled retrofit programs. Also, the EPA is presently considering the promulgation of I/M measures for Dallas-Fort Worth.

Table 2-7. (Continued)
List of AQCR's Which Will Implement Measures to Reduce Emissions Per Vehicle Mile of Travel

AQCR	I/M			Retrofit				-SSVC	
				VSAD		Air Bleed			
	Test Type	Ownership	Area Covered	Vehicle Year	Area Covered	Vehicle Year	Area Covered	Stages	Area Covered
Sacramento	Loaded	Public	AQCR	1955-65	AQCR			I & II	AQCR
San Joaquin	Loaded	Public	AQCR	1955-65	AQCR			I & II	AQCR
Puget	Idle	Private	AQCR			Pre-68	AQCR		
Portland	Idle	Public	Portland SMSA			Pre-68	Oregon part of AQCR		
East Washington, Idaho	Idle	Private	Spokane SMSA			Pre-68	Spokane SMSA		
Northern Alaska	Idle	Public	City of Fairbanks & North Star Borough			Pre-68	AQCR		
Austin-Waco								I	AQCR
Dallas - Ft. Worth								I & II	AQCR
El Paso								I & II	El Paso SMSA & Texas Counties of AQCR

INSPECTION AND MAINTENANCE PROGRAMS

Analysis of the inspection and maintenance program costs has been limited to the programs operating in Chicago and New Jersey. In both instances, the programs make use of idle mode tests, and the inspection stations are state owned and operated. Reference 11 presents a description of these inspection programs as well as estimated fixed and operating costs for a publicly owned and operated emissions inspection program. A brief description of the assumptions used in estimating costs of inspection and maintenance programs follows. Cost elements have been computed by the EPA Office of Land Use and Transportation Policy, based on data provided by Northrop/Olsen Corporation[20], The City of Chicago[21], and the State of Arizona[22]. It is assumed that the inspection facilities would be either publicly or privately owned and operated with the needed maintenance of rejected automobiles performed at privately owned garages or repair facilities. The number of inspection lanes required is computed from the projected light-duty vehicle population for that area for the year of program implementation and the following standard lane capacities:

- Idle Mode - 32,000 vehicles per lane per year
- Loaded Mode - 25,000 vehicles per lane per year.

These capacities assume an 8-hour working day for 250 days per year with an average of 40 percent idle time. Since vehicles are not expected to arrive at inspection stations at a uniform rate, some idle time is inevitable. However, the extent of this idle time largely depends on the inspection schedule and other measures in an area that would affect the distribution of vehicle arrivals. The success of each area in achieving greater uniformity in arrival rates cannot be estimated at this time; therefore, 40 percent idle facility time has been assumed. It should be recognized that as areas become experienced in administering inspection and maintenance programs, the idle facility time is expected to be significantly lower than 40 percent. In this sense, the cost estimates appear to be overstated for the later years of the 10-year period. The number of stations required was computed assuming that all stations have two lanes.

The total annual cost of an inspection station is assumed to range from $106,077 to $130,974, depending on the following factors:

- Ownership (private versus public)

- Test type (loaded versus idle)
- Geographic location which determines the total site cost.

Table 2-9 presents the summary of costs assumed per two-lane station. Reference 11 gives the detailed breakdown of the cost estimate. The second cost area in the program is the maintenance of failed vehicles. An average tune-up cost of $30 per failed vehicle, of which $15 is assumed to be attributable to the inspection and maintenance measure, is considered. Vehicles that fail the emissions inspection and subsequently are tuned are expected to incur fuel savings. The extent of annual fuel savings from the program is dependent on the failure rate among other things. EPA's Office of Transportation and Land Use Policy estimates that on the basis of recent data the following relationship exists between the failure rate and annual fuel savings for serviced vehicles: $Y = 31.5X^{-0.514}$, where X=percent failure rate and Y=annual fuel savings, expressed in percents, for serviced vehicles. Fleet-wide dollar savings are computed for each AQCR by computing the fuel saving rate from the above equation and assuming an annual vehicle use of 10,000 miles, a fuel consumption rate of 13.58 miles per gallon, and a price of gasoline of $0.75 per gallon.

Based on the inspection cost estimates given in Table 2-8 and the maintenance cost and fuel savings assumptions outlined above, the annual inspection and maintenance fixed and operating costs for each AQCR have been computed for the years 1976-85. The summary annual costs for the United States are presented in Table 2-9. As shown in the table, the fuel savings more than offset the costs of the inspection and maintenance program, and in fact, result in an overall net benefit, even after considering all TCP costs.

Table 2-8.
Fixed and Operating Cost of a Two-Lane Inspection Station

(In 1975 Dollars)

Cost Category	Public Loaded	Public Idle	Private Idle
Capital Costs			
Equipment			
• Instrumentation	$11,870	$11,870	$11,870
• Automated System	14,850	14,850	0
• Dynamometer	6,400	0	0
Installation Costs	5,000	3,000	6,000
Site costs[3]	14,000-140,000	14,000-140,000	0
Construction Costs[4]	35,000	35,000	0
Administration and Miscellaneous[1]	3,000	3,000	3,000
Contingencies[2]	4,500-10,800	4,090-7,000	1,040
Total Capital Costs	$94,620-226,920	$85,810-214,720	21,910
Annual Costs:			
Annual Capital Costs[5]	$17,064-30,974	$15,630-28,907	$6,077
Operating Costs			
• Salaries[6]	64,000	64,000	64,000
• Supplies	2,940	2,940	2,940
• Administrative Support and Overhead	33,060	33,060	33,060
Total Annual Costs	$117,064-130,974	$115,630-128,907	$106,077

[1] Administrative and miscellaneous costs are assumed to be $3,000 per station for the first year.

[2] Unforeseen contingency costs are calculated as 5 percent of the total cost for equipment, installation, land, construction, and administration.

[3] 14,000 Square feet at $1.00 to $10.00 per square foot.

[4] 2,500 Square feet at $14.00 per square foot. For private stations it is assumed that present facilities will be adequate to house the small amount of equipment needed for inspection.

[5] Assuming an economic life of 40 years for land and 10 years for other capital costs at 10 percent annual interest and with zero scrap value. The administrative and miscellaneous costs which are incurred for the first year only are assumed to be non-depreciable.

[6] One supervisor at $16,000 and 5 inspectors at $9,600 each per year.

Table 2-9.
Aggregate Cost (Benefit) of Inspection and Maintenance Programs, 1976-85

(In Millions of 1975 Dollars)

			Operating & Maintenance (O/M) Costs					
Year	Capital Investment (1)	Annualized Capital Costs (2)	Station O/M Costs (3)	Owners' Maintenance Cost (4)	Fuel Savings (5)	Net O/M (6) (3+4-5)	Annual Costs (7) (2+6)	Cumulative (8)
1976	141.9	18.4	104.4	186.0	385.9	(95.5)	(77.1)	(77.1)
1977	3.4	18.8	103.8	190.8	395.7	(101.1)	(82.3)	(159.4)
1978	3.3	19.2	106.4	195.5	405.5	(103.6)	(84.4)	(243.8)
1979	3.7	19.7	109.1	200.3	415.5	(106.1)	(86.4)	(330.2)
1980	3.8	20.2	111.9	205.2	425.6	(108.5)	(88.3)	(418.5)
1981	2.6	20.6	114.0	209.6	434.7	(111.1)	(90.5)	(509.0)
1982	3.2	21.0	116.4	214.2	444.0	(113.4)	(92.4)	(601.4)
1983	3.0	21.4	118.6	218.7	453.3	(116.0)	(94.6)	(696.0)
1984	3.4	21.8	121.1	223.4	462.9	(118.4)	(96.6)	(792.6)
1985	3.0	22.2	123.4	228.1	472.5	(121.0)	(98.8)	(891.4)
Totals	171.3	203.3	1,129.1	2,071.8	4,295.6	(1,094.7)	(891.4)	-

RETROFIT PROGRAMS

Vacuum Spark Advance Disconnect (VSAD). VSAD retrofits are mainly applicable to pre-1967 vehicles as shown in Table 2-7. It is assumed that the installation cost of a VSAD retrofit would be approximately $20.00 per vehicle, and it is estimated that the annual maintenance cost would be approximately $5.00 per vehicle. VSAD retrofits are expected to increase fuel use from 0 to 2 percent, which translates to a maximum annual fuel penalty of $11.25 per vehicle, assuming a fuel consumption rate of 750 gallons at $0.75 per gallon.

Air Bleed. The 11 AQCR's that will be implementing air-bleed retrofit programs are listed in Table 2-7. Air bleed devices are primarily applicable to pre-1968 vehicles although some areas, such as Baltimore and Boston, extend the applicability to 1971 model year vehicles. The installation cost of an air bleed retrofit is assumed to be $40 per vehicle for simple air bleed devices and $55 per vehicle for air bleed devices with exhaust gas recirculation (EGR). It is further assumed that the life of the devices is 5 years, necessitating replacement of the equipment after that period at the same cost. However, air bleed devices are expected to increase the fuel economy by approximately 4 percent. This fuel economy benefit translates to $22.50 per year per vehicle. Therefore, the net benefit over the 5 year life of the units would be $72.00 per vehicle with a simple air bleed device and $57.50 per vehicle with an air bleed/EGR device.

Summary Costs of Retrofits. The summary aggregate costs of the retrofit programs for 1976 through 1985 are presented in Table 2-10.

Table 2-10.
Summary Costs of Retrofit Programs, 1976-85

(In Millions of 1975 Dollars)

Retrofit Program	1976[1]	1977	1978	1979	1980	1981	1982	1983	1984	1985
VSAD	34.5	27.0	13.9	10.2	7.8	6.6	6.3	6.3	6.3	6.3
Cumulative	34.5	61.4	75.4	85.6	93.4	100.0	106.3	112.6	118.9	125.2
Air Bleed	--	69.2	(46.4)[2]	(33.4)	(23.5)	(16.1)	12.1	(8.1)	(7.1)	(6.5)
Cumulative		69.2	22.8	(10.6)	(34.1)	(50.2)	(38.1)	(46.2)	(53.3)	(59.8)
Totals	34.5	96.2	(32.5)	(23.2)	(15.7)	(9.5)	18.4	(1.8)	(0.8)	(0.2)
Cumulative	34.5	130.7	98.2	75.0	59.3	49.8	68.2	66.4	65.6	65.4

[1] Only California AQCR's will implement VSAD in 1976.

[2] Numbers in parentheses indicate negative value, i.e., economies gained by implementation of these retrofits.

SERVICE STATION VAPOR CONTROLS

The recent controversy about the Stage II Vapor Control Systems (simple balance and vacuum-assist) creates uncertainty as to the type of system which will be implemented. The installation cost of a vacuum-assist system is significantly higher than the simple displacement system. Using the simple balance method, costs per station may run between $2,000 (for a new station) and $5,000 (for existing stations) for the required equipment labor. Vacuum-assist equipment costs anywhere from one and a half to two times as much. For a 75,000 gallon per month service station, the University of California, San Diego, estimates the investment costs at $6,727 and $14,681 for simple balance and vacuum-assist systems, respectively.[23]

In estimating the investment and operating cost of service station vapor control systems, it is assumed that for Stage II controls, one-third of the systems implemented will be simple balance and two-thirds will be vacuum-assist. Based on EPA's most recent data, the investment and operating costs of the systems are assumed to be as follows:

	Blower-Assist	Simple Displacement
Investment		
Service station component (Stage II)	$12,000	$8,000
Support facilities component (Stage I)	1,300	1,300
Total per station	$13,300	$9,300
Operating costs per station per year	$ 556	$ 556

For Stage I systems, a fuel savings benefit of $594 would result, assuming 90 percent efficiency in recovering 880 gallons per station at $0-75 per gallon. For Stage II, the fuel savings benefit would be $495 for simple balance systems, assuming 75 percent recovery, and $627 for vacuum-assist systems, assuming 95 percent recovery. Table 2-11 presents the summary costs of service station vapor controls for the 10-year period.

Table 2-11.
Aggregate Costs of Service Station Vapor Control Programs, 1976-85

Annual Costs (In Millions of 1975 Dollars)

Year	Fixed	Operating	Total	Cumulative
1977	$46.4	$(14.2)	$32.2	32.2
1978	46.4	(14.2)	32.2	64.4
1979	46.4	(14.2)	32.2	96.6
1980	46.4	(14.2)	32.2	128.8
1981	46.4	(14.2)	32.2	161.0
1982	46.4	(14.2)	32.2	193.2
1983	46.4	(14.2)	32.2	225.4
1984	46.4	(14.2)	32.2	257.6
1985	46.4	(14.2)	32.2	289.8

SUMMARY COSTS

Table 2-12 shows the summary costs associated with measures that will reduce emissions per vehicle mile. Table 2-13 shows the breakdown between capital costs and operating and maintenance costs for each control program for the period from 1976 to 1985.

Approximately 90 percent of the total cost for reducing emissions per vehicle mile is attributable to the inspection and maintenance programs. Several factors account for the large costs of inspection and maintenance relative to retrofit and service station vapor controls. Perhaps the most significant is the annual operating cost, which is estimated to be $100,000 per station. Furthermore, because of the random vehicle arrivals for inspection, it is assumed that the stations will be idle 40 percent of the time and therefore they will not operate at optimum capacity. This idle factor obviously offers some potential for economy and reduction of overall costs; however, the amount of idle time that could be utilized is indeterminable at this time.

A second factor that contributes to the large cost of inspection and maintenance programs is that essentially every vehicle in the control area must submit to the inspection, and those that fail will require maintenance and reinspection, whereas retrofit systems usually apply only to a small portion of the total number of vehicles. Finally, retrofit and service station vapor control cost estimates include some partially compensatory economies, whereas no fuel economies are considered for inspection and maintenance programs.

Table 2-12.
Summary of Costs for Measures that Reduce Emissions Per Vehicle Mile

Measure	Annual Costs (In Millions of 1975 Dollars)									
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Inspection/ Maintenance (I/M)	309	313	321	329	337	344	352	359	366	374
I/M Fuel Savings	(386)	(396)	(406)	(416)	(427)	(435)	(444)	(453)	(463)	(473)
Net I/M Costs	(77)	(83)	(85)	(87)	(90)	(91)	(92)	(95)	(97)	(99)
Retrofit	35	96	(33)	(23)	(16)	(10)	18	(2)	(1)	0
Service Station Vapor Control	--	32	32	32	32	32	32	32	32	32
Net TCP Costs	(42)	45	(86)	(78)	(74)	(69)	(42)	(65)	(66)	(67)
Cumulative	(42)	3	(83)	(161)	(235)	(304)	(346)	(411)	(477)	(544)

Note: Totals in this table differ somewhat from totals in other tables because of rounding.

Source: Tables, 2-9, 2-10, and 2-11.

Table 2-13.
Investment and Operating Maintenance Costs for Measures Which Reduce Emissions Per Vehicle Mile Travelled 1976-85

(In Millions of 1975 Dollars)

	Total Program Costs	Investment Costs	Operating and Maintenance Costs	Fuel Savings[1]
Retrofit				
VSAD	$125.2	$ 22.1	$103.1	
Air Bleed	(59.8)	153.4	(213.2)	
Subtotal	$ 65.4	$175.5	$(110.1)	
Inspection/ Maintenance	($891.4)	$203.3	$3,200.9	($4,295.6)
Service Station Vapor Controls	289.8	285.1	4.7	
Totals	($536.2)	$663.9	$3,095.5	($4,295.6)

[1] Because the fuel savings associated with the inspection and maintenance measure have such a sizeable impact on overall TCP costs, they are broken out separately.

COST OF IMPLEMENTING MEASURES THAT REDUCE VMT

The implementation of measures to reduce automobile emissions by reducing VMT will affect many aspects of urban activity other than air quality. Some non-air quality aspects are:

- Energy consumption. Transit systems are considerably more energy efficient than the automobile. Bus transit uses approximately 3,600 Btu's per passenger mile compared to 8,000 Btu's in work trips by automobile. Therefore, reduction in automobile use achieved by diverting automobile travelers to transit buses will reduce energy consumption. Reductions in automobile use achieved through carpooling will also result in energy savings that are approximately proportional to VMT reductions.

- Transportation noise. The diversion of automobile travelers to public transit appears to be capable of reducing exposure to highway-generated noise. A study of the I-66 corridor near Washington, D.C., indicates that the transit option decreases exposure to elevated noise levels by 10 to 20 percent, depending on the noise level, whereas the highway option increases exposure to noise by as much as 47 percent.[24]

- Traffic safety. Transit buses have roughly one fatality per 100 million passenger miles[25] compared to about 1.6 fatalities per 100 million passenger miles for automobiles in urban areas.[26],[27] Bus accident costs per passenger mile are roughly two-thirds those of automobiles.[28],[29]

- Traffic congestion and highway construction. Buses require roadway space of less than 2 automobiles, but carry up to 50 times as many passengers per vehicle as automobiles. Thus, the diversion of automobile drivers to public transit as well as to carpools will reduce traffic volumes and congestion. Furthermore, reduced congestion will result in reduced need for further highway construction.

- Travel times. Transit buses require more time than the automobile for access, collection, and distribution. These transit time disadvantages can be offset by the use of express bus routes and priority treatment for transit vehicles. Carpools have also a time disadvantage relative to the single-occupant automobile. This diadvantage is incurred during collection and distribution and, as in the case of bus transit, it can be offset to some extent by the provision of priority treatment.

Many of the non-air quality effects listed above are beneficial and would make the implementation of the control measures desirable even if air quality were not a problem. Indeed, the transportation measures that have been proposed to improve air quality have also been proposed to alleviate non-air quality related urban transportation problems.

There has been little direct experience with many transportation control measures or with changes in transportation system attributes of the magnitude contemplated in some TCP's. Certain types of costs, i.e., those associated with the changes in urban land use due to transportation control measures in this category, are particularly difficult to estimate.[30] Another source of difficulty stems from the joint benefits derived from transportation control measures. Although costs for a transit improvement program could be estimated with reasonable accuracy, it would be inappropriate to assign the full cost to the cause of achieving air quality. Other non-air quality benefits should share an appropriate portion of the total cost. Another source of difficulty of estimating costs of transportation control measures is that these costs are highly dependent on the specific control measures implemented and the manner and area in which they are implemented. Finally, AQCR's have not yet specified the specific VMT measures they will adopt. For these reasons, the costs of transportation control measures related to reductions in VMT are not estimated in this report.

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Section Three

THE ECONOMICS OF WATER POLLUTION CONTROL

Chapter 1
Summary

The economics of controlling water pollution encompasses both the expected benefits and the probable costs of control. The principal findings in the control cost area are summarized below; benefits of water pollution control are discussed in the next section of this chapter.

The benefits from controlling water pollution are the result of reduced levels of pollutants in the nation's waterways. Table 1 presents estimates of the amount of various pollutants that are expected to be introduced into the waters from 1971 to 1985.

Table 1.
National Trend in Effluent Discharge Levels

Water Pollutants	1971	1975	1977[1]	1983[2]	1985
	Net Weight (Metric Tons)				
Industrial and Electrical Energy:					
BOD	2,067,693	1,966,001	1,315,045	687,652	573,299
Suspended solids	6,744,996	6,235,049	3,405,300	771,352	444,866
Dissolved solids	11,343,849	11,496,225	11,488,062	9,714,877	9,305,820
Nutrients	86,203	81,596	54,297	39,249	38,609
Acids	293,623	224,038	80,836	68	13
COD	3,353,814	3,312,273	2,851,155	988,144	1,675,683
Municipal Sewage[3]:					
BOD	1,693,273	1,586,893	1,437,390	806,400	702,669
Suspended solids	1,820,621	1,668,368	1,429,736	983,516	822,032
Nutrients	1,014,442	1,061,768	1,080,451	1,085,340	1,084,620

[1] All BPT installed
[2] All BAT installed
[3] Municipal sewage figures are based upon the following assumptions:
    a. Percentage of population sewered: 1970(71.0), 1974(75.0), 1990(83.0)
    b. Percentage of sewered population by type:
        -Primary: 1971(21.3), 1974(21.0), 1977(20.0), 1985(0.0)
        -Secondary: 1971(62.3), 1974(62.6), 1977(67.5), 1985(81.2)
        -Tertiary: 1971(1.4), 1974(4.4), 1977(6.5), 1985(18.8)
        -No Treatment: 1971(15.0), 1975(12.0), 1977(6.0), 1985(0.0)
    c. Removal efficiency of BOD, SS, Nitrates, Phosphates--by type :
        -Primary: 38, 60, 0, 0
        -Secondary: 85, 85, 0, 0
        -Tertiary: 97, 98, 91, 90

The direct costs of water pollution control will be incurred as expenditures to install and operate equipment, to control the pollution from "point sources" (i.e., those with channelized waste streams), and to prevent sediment and other run-off from "nonpoint sources".

On the basis of the results of the 1976 Needs Survey (Final Report to the Congress, February 1977 "Cost Estimates for Construction of Publicly-Owned Wastewater Treatment Facilities"), the largest single category of required expenditures is that required for the collection and treatment of municipal sewage and stormwater, $150 billion (in 1976 dollars as reported in Needs Survey) by 1990. These expenditure requirements have been divided into six categories, depending on the required treatment levels, and/or the type of construction as follows:

1. Category I - Secondary Treatment.
2. Category II - More Stringent Treatment Required by Water Quality (removal of phosphorus, ammonia, nitrates, and organic pollutants).
3. Category IIIA - Correction of Sewer Infiltration/Inflow.

   Category IIIB - Major Sewer Rehabilitation.
4. Category IVA - Collector Sewers.

   Category IVB - Interceptor Sewers.
5. Category V - Correction of Combined Sewer Overflows.
6. Category VI - Treatment and/or Control of Stormwaters.

In Table 2, an aggregated summary of municipal costs is presented for the two basic scenarios used in this report: Federal outlays (and associated state and local expenditures) resulting from current contract authority, and Federal outlays resulting from a recommended additional contract authority of $4.5 billion per year beginning in FY1978 and continuing for ten years. Comparing the total investment under these two scenarios with the estimate $150 billion (in 1973 dollars) from the Needs Survey indicates that neither program will meet the estimates of actual requirements, although the higher scenario will meet 84 percent of the "backlog" needs in Categories I through V.

Table 2.
Summary of Municipal Costs
(Millions of 1973 Dollars)

Federal Grant Authority	1976-85 Investment	1985 O&M	1985 Annualized Capital
Current	26.4	1.45	4.23
Additional $4.5 Billion per Year (Beginning in 1977)	63.3	3.48	10.1

Industrial water pollution control investment expenditures over the same 1976-85 period will amount to approximately $52 billion(1975$). These expenditures are only 35 percent of the municipal costs reported in the 1976 Needs Survey but are higher than the "current-authority" municipal expenditures by 96 percent. The anticipated water pollution control costs from 1976 to 1985 are presented for each major water polluting industry in Table 3, and Figures 1 and 2.

Table 3.
National Industrial Investment Costs for Water Pollution Costs (Millions of 1975 Dollars)[1]

Industry	1974-1977	1978-1983	1976-1985
GROUP I			
Feedlots	50	24	54
Beet Sugar	12	19	28
Cane Sugar	22	22	28
Dairy	54	1,035	1,096
Fruits & Vegetables	35	429	479
Grain Milling	NEG	144	145
Meat & Poultry Processing	117	1,134	1,210
Seafood	40	1,122	1,292
Leather	48	265	295
Textiles	134	453	558
Builders Paper	11	129	138
Pulp and Paper	1,963	4,503	6,654
Plywood, Hardboard and Wood Preservation	71	43	425
Inorganic Chemicals	632	333	516
Fertilizers	111	173	285
Organic Chemicals	678	4,457	5,403
Phosphates	69	77	131
Plastics & Synthetics	348	1,099	1,454

Table 3. (Continued)
National Industrial Investment Costs for Water Pollution Costs (Millions of 1975 Dollars)[1]

Industry	1974-1977	1978-1983	1976-1985
GROUP I (Cont'd.)			
Petroleum	1,562	524	1,770
Rubber	85	84	148
Ferroalloys	15	50	95
Iron and Steel	1,760	1,800	3,120
Bauxite Refining	63	61	111
Primary Aluminum	29	24	45
Secondary Aluminum	3	52	55
Copper	14	11	15
Primary Lead	3	2	3
Primary Zinc	8	15	18
Asbestos	1	2	3
Cement	37	18	39
Fiberglass	15	18	29
Flat Glass	2	4	6
Pressed & Blown Glass	16	174	229
Electroplating	1,995	2,793	3,837
Steam Electric Power	600	3,900	4,800
Soaps & Detergents	6	69	75

Table 3. (Continued)
National Industrial Investment Costs for Water Pollution Costs (Millions of 1975 Dollars)[1]

Industry	1974-1977	1978-1983	1976-1985
GROUP II			
Fabricated Metals	3,579	4,223	6,035
Machinery-Electrical	1,144	1,588	2,301
Machinery-Nonelectrical	3,165	4,068	5,318
Transportation Equipment	2,147	2,361	3,527
NATIONAL TOTALS	20,650	37,300	51,800

[1] Detailed independent studies of several of these industries were recently completed for EPA by various consultants. The revised estimates are presented here, with explanations of the differences from SEAS estimates in the individual industry descriptions.

[2] Group II industries were analyzed by Gianessi and Peskin with different sub-categorizations. ("The Cost to Industries of the Water Pollution Control Amendment of 1972," National Bureau of Economic Research, December 1975--Revised January 1976.) The total overall industries in this group for their study was $9,870 million for BPT. This compares very favorably with the SEAS total of $10,340 million. For purposes of national impact analysis, both estimates are within an acceptable range of computational variance.

Figure 1.
Total Industrial Capital Investment
for Water Pollution Abatement

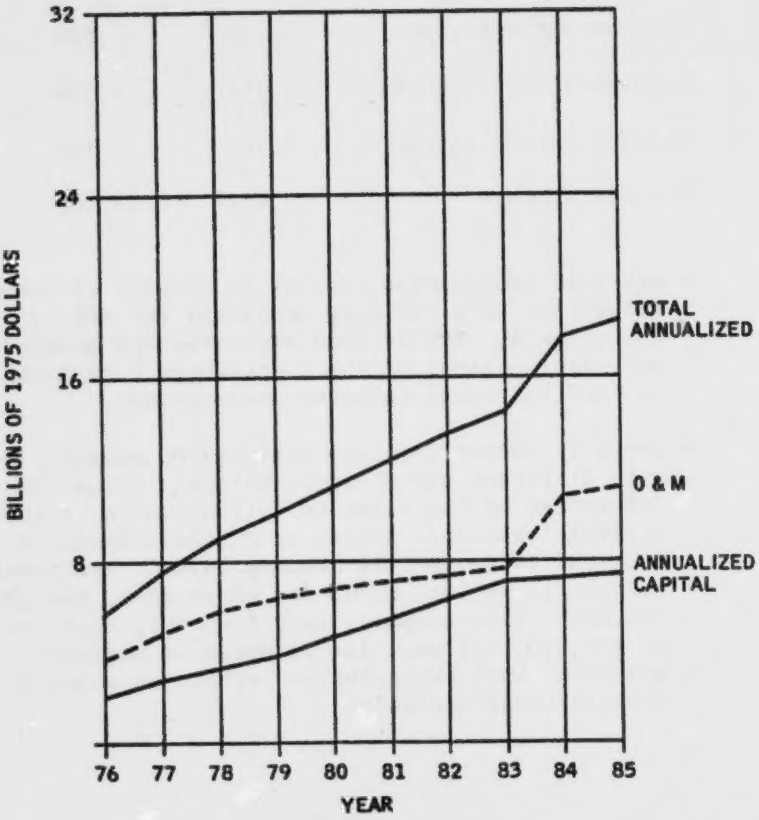
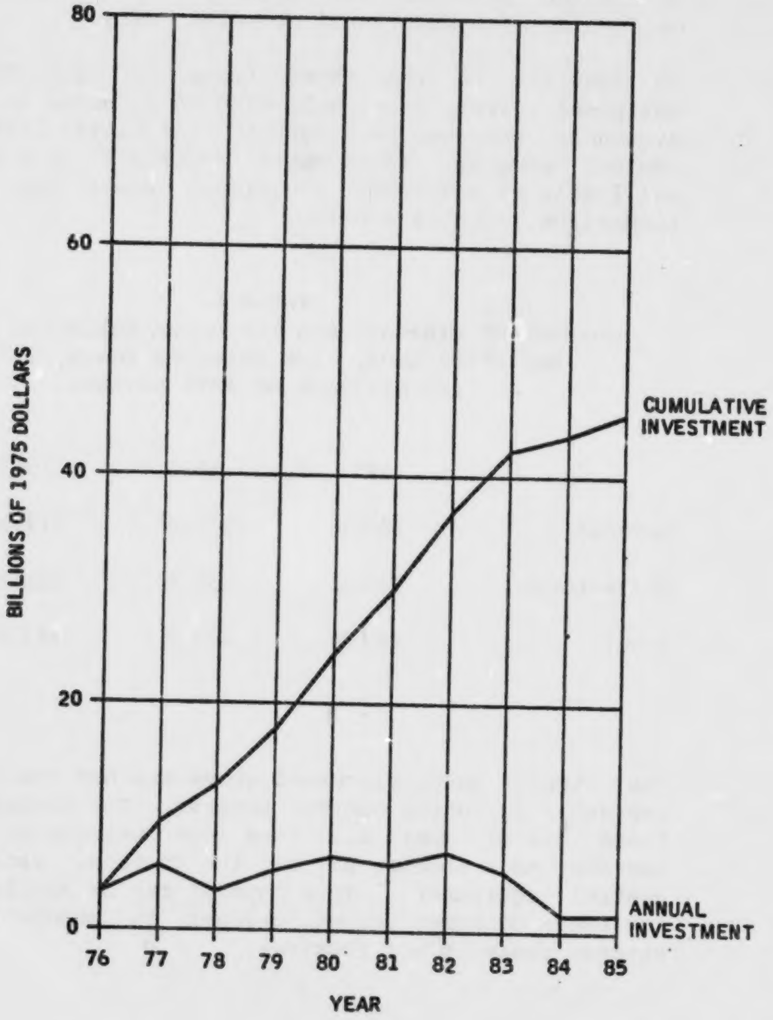


Figure 2.
Industrial Annualized Capital Investment and Operation and Maintenance Expenditures for Water Pollution Abatement



Estimating the costs of nonpoint-source water pollution control is much more difficult. Not only has little work been done in this area, but both the amount of pollution to be controlled and the appropriate methods of control depend on such complex variables as annual rainfall characteristics and local soil conditions. Control and implementation strategies are not sufficiently well-defined to allow estimation of agricultural nonpoint costs.

In addition to the expenditures for pollution control equipment, direct costs will also be incurred to operate the government programs necessary to administer the pollution control program. These costs, which will be experienced at all levels of government - national, state, and local, are summarized in Table 4 below.

Table 4.
Government Expenditures for Water Pollution Federal and State-Local, for Selected Years, 1975-85
(In Millions of 1975 Dollars)

	1977	1983	1985
Federal	367.9	311.9	311.9
State-Local	130.0	130.0	130.0
Total	497.9	441.9	441.9

The direct costs discussed above are not the only costs of the water pollution control program. The burden of meeting these direct costs will have repercussions on society, and industry must somehow pay for the costs of water pollution control equipment. This payment may be manifested through increased consumer prices, changes in production, or, in extreme cases, plant closures.

Chapter 2
The Benefits of Controlling Water Pollution

This section of the report presents a state-of-the-art assessment of the national benefits of controlling water pollution. A broad spectrum of studies has been reviewed for information on water pollution control benefits. The information is fragmentary and localized, requiring questionable extrapolations to develop estimates at the national level. Table 1 summarizes the availability and reliability of the information contained in these studies.

Table 1.
Availability and Reliability of Information on Water Pollution Damages

Pollutant	Health	Aesthetic and Ecological	Outdoor Recreation	Product. Losses	Prop. Values
Acidity	U	U	SF	SP	U
BOD	U	SP	IF	IF	U
Coliform Bacteria	SP	U	SF	SP	U
Color	U	U	U	U	U
Floating Solids	U	U	IF	SP	U
Hardness	U	U	U	IP	U
Nutrients	U	U	SP	SP	U
Odor	U	U	U	U	U
Oil	U	SP	SP	SP	U
Pesticides	U	U	U	U	U
Sediment	U	IF	IF	IF	SP
Temperature	U	SP	IF	SP	U
TDS and Salinity	U	U	U	IF	U
TSS and Turbidity	U	U	SF	SP	U
Toxic Metals	U	U	SP	SP	U
General Pollution	SP	SP	AF	IF	SF

Availability:	Reliability:
A - ample	E - excellent
I - insufficient	G - good
S - scarce	F - fair
U - unavailable	P - poor

Future refinements in the data and techniques used for estimation should lead to a better understanding of the damage sources, as well as more precise estimates for respective damages.

HEALTH DAMAGES

Nature and Effects of Water Pollution Damage to Health

The negative effects of water pollution on health were the earliest motivation for water pollution control. Even at present levels of wastewater treatment and municipal water supply treatment, harmful pollutants can be ingested and cause disease. Bacteria and viruses are the primary pollutants threatening human health, although recent attention has also focused on carcinogens. Among the diseases that have been investigated are gastroenteritis (including nausea, stomach cramps and diarrhea), infectious hepatitis, menengitis, congenital heart anomalies, and acute myocarditis and pericarditis. The existing literature must be considered inadequate because of the number of pollutants and diseases for which there is insufficient statistical correlation.

Survey of Source Studies

A survey of health damage studies was accomplished by Neri, Hewitt, and Schreiber (1974), who surveyed nearly 50 international epidemiological studies. Unger, Emerson, and Jordening (1973) present a graphic display of health impact, effect transmission, and pollutant relationship in their study. Nearly all health benefit studies rely on the Craun and McCabe (1971) damage estimate of reported outbreaks of waterborne illnesses. The Environmental Protection Agency (EPA) is currently studying the impact of water pollution on human health by examining the relationship between water quality and the absenteeism of elementary school children.

OUTDOOR RECREATION DAMAGES

Nature and Effects of Water Pollution Damages to Recreation

Because of the strong dependence associated with water-related recreation to water quality, recreation accounts for a major part of the damages caused by water pollution. Swimming, boating, and fishing are among the most popular outdoor activities; the various pollutants discharged into our waterways clearly interfere the enjoyment of these activities.

Swimming and other primary water-contact sports that provide a likelihood of swallowing water are most strongly affected, as is evident by the water quality criteria developed by the Committee on Water Quality Criteria who set requirements of fecal coliform, pH, clarity, and color. However, surveys have made it clear that much more than these health considerations influence the quality of water-based recreation. For example, fishing clearly depends on the capability of the water to support wildlife which is affected by a number of water quality parameters, especially dissolved oxygen, high temperatures, pH, phenols, turbidity, ammonia, dissolved solids, nitrates, and phosphates.

The aesthetic experience of being in, on, or near water strongly influences the pleasantness of all water recreational activities. The measures of water quality that are most highly-valued in people's perceptions of its aesthetic attractiveness have been the major target of studies done by survey researchers. They include floating debris and oil, odor, clarity, and color; these conditions can cause a reduction in the quality and value of the recreation experience, making it less enjoyable. Secondly, pollutants can increase the costs of obtaining a satisfactory recreational experience. Such increased costs arise primarily from increases in extended travel to gain access to sufficiently clean water, but they can also result from additional equipment or maintenance expenses. Both decreased quality and increased cost ususally lead to a reduction in the frequency or intensity of using available recreation sites.

Water pollution also decreases the value of recreational experiences. The study by Ditton and Goodale (1972) also estimated that 21 percent of the existing users would experience higher value from recreation if pollution were reduced by 1 percent. The extent of increased value was estimated using Ericson's data on willingness to pay for avoiding polluted water. This estimate, which amounted to $5.75 per recreation day, was developed for tourists in Colorado.

Survey of Source Studies

An excellent survey of nearly 50 outdoor recreation damage studies is provided by Jordening (1974). The survey presents tables containing over 30 water characteristics or constituents that are detrimental to water-based recreational activity, as well as reported damages and established critical levels of specific pollutants.

Major source studies employed in contemporary calculation of damages and their respective subject areas are presented below:

- Council on Environmental Quality (1972) - water quality
- Ericson (1975) - value of recreation experience
- Ditton and Goodale (1972) - recreationists' reaction to water quality
- U.S. Fish and Wildlife Service (1972) - recreation days and travel mileage
- U.S. Bureau of Outdoor Recreation (1972) - recreation days
- Owens (1970) - travel mileage and average speed of recreationists
- Burt and Brewer (1971) - travel cost of recreationists
- U.S. Federal Highway Administration (1974) - cost of operating an automobile
- Walker and Gauger (1973) - value of household work.

Unger *et al.* (1974) presents two approximations of the damages to outdoor recreation from water pollution. Two regional studies, (Reiling *et al.*, 1973 and Nemerow and Faro, 1970), were synthesized to extrapolate national damages through demand analysis. Total damages were computed as a product of damages per acre, the percentage of polluted water, water surface area, and a constant factor to compensate for substitutions in the water-based recreations. The expenditure method that equates benefits and expenditures is an alternative method of estimating outdoor recreational benefits. U.S. Bureau of Outdoor Recreation (1967 and 1972) and U.S. Fish and Wildlife (1972) studies were the primary sources for this estimate. In a current EPA study of the recreational benefits from water quality improvement, empirically derived damage functions will be formulated to approximate the impact of water quality changes on recreation demand.

AESTHETIC AND ECOLOGICAL DAMAGES

Nature and Effects of Water Pollution Damages on Aesthetic and Ecological Values

Aesthetic and ecological values are damaged by water pollution in a number of ways. Users of water in such activities as recreation and to some extent, production, also suffer damages because the quality of their experience has been degraded by the presence of pollutants. Non-users also suffer damages which they would be willing to pay to avoid even though they do not intend to make direct use of the waters involved. These aesthetic and ecological values result from the knowledge that clean and natural waterways exist and will be preserved and protected from the danger of ecological loss. A part of such willingness to pay is the vicarious satisfaction derived from the knowledge that the preserved waterway will be used and enjoyed by others, even the members of future generations to whom the natural environment is bequeathed.

Damages to non-users result from those pollutants that have the greatest impact on the readily-sensible aspects of water quality; these include floating debris and oil, clarity, color, and odor. Reduced ability to support wildlife would certainly be considered damaging from the perspective of those non-users who place high value on these ecological aspects of water quality.

Survey of Source Studies

The primary source study used in estimating the national aesthetic and ecological damages was the study performed in British Columbia by Meyer (1974). This study focused on the Fraser River, a major waterway in Canada, surveyed residents' willingness to pay for fishing and preservation of the salmon population. Households were sent a carefully developed questionnaire that placed questions concerning the value of the salmon resource in the context of public service purchases made by the local municipal governments. Respondents were asked to indicate the value they would place on preservation of the river's resources, even though they did not expect to use them. The results indicated an average annual willingness to pay of $223 per household, adding 54 percent to the value of fishing.

Colorado State University is conducting a study, Option Value as a Benefit of Water Quality and Improvement - 1976, which will provide an empirical-based estimate of individuals willing to pay to assure future access to clean water resources.

PRODUCTION DAMAGES

Water pollution causes increased production costs and decreased output because clean water is an important factor in the production of many goods and services. For purposes of this report, production uses of water have been grouped into the following classes:

- Municipal
- Domestic (i.e., household)
- Industrial
- Agricultural
- Commercial fisheries
- Materials damage.

Nature and Effects of Water Pollution Damage to Production

Water pollutants cause damages to municipal water supplies increasing both the extent of water treatment required to produce potable water, and the costs of maintaining water treatment and supply equipment. The most damaging pollutants are suspended and dissolved solids, bacterial and viral pathogens, metal ions, (particularly iron and manganese), inorganic and organic chemicals, and other sources of bad odor and taste. The municipal water treatment operations affected by additional pollutants are decoagulation, filtration, clarification, demineralization and softening, and control of taste and odor. Although disinfection is a major part of municipal water treatment, it now appears that this operation would not be substantially reduced by controlling man-made effluents.

Although most household water is drawn from treated surface waters or relatively clean groundwater sources, even these supplies contain damaging pollutants; the remaining effects cause damage to water pipes, water heaters, fixtures, appliances, fabrics, swimming pools, shrubbery and lawns, primarily from dissolved solids and acidity. A major difficulty in the assessment of these damages arises from the need to isolate the man-made effects from natural pollution levels.

The major industrial uses of water are for cooking, boiler feed, and processing. About 25 percent of the 174 billion liters per day drawn from surface water is treated before use. Boiler feed water must be demineralized and given tertiary treatment before use, but this process would be necessary for natural pollutants only. Cooling water, which accounts for more than 67 percent of industrial water intake, is not highly sensitive to pollution, although fouling can cause reduced heat-transfer rates, and some pollutants reduce equipment life. Although the most troublesome pollutants vary substantially upon application use, biological organisms, suspended and dissolved solids, and acids are among those most widely treated. The industries most sensitive to pollutants in their water supply are those producing pharmaceuticals, foods and beverages, chemicals and textiles.

The pollutants most damaging to agriculture are suspended and dissolved solids, and micro-organisms. Salinity can reduce crop yields and the range of crop varieties that can be economically raised under irrigation. Sediments can be damaging to some clay soils, but have their greatest impact on irrigation ditches, pumps, and nozzles. Bacteria and viruses are of concern because of their potential damage by crop contamination and the spread of disease to livestock.

Water pollution has seriously damaged commercial fisheries by reducing the size of the catch, increasing its cost, and lowering its quality. Fecal coliform and other bacteria, reduced oxygen, and toxic metals, such as mercury, have caused the closing of about 20 percent of marine shellfishing areas. National shellfish catches have dropped by more than half since the turn of the century. For example, oyster production in Chesapeake Bay, has dropped from 12 million to 1 million bushels per year.

The damage to materials by water pollution arises in a number of the above categories and has been included wherever appropriate. Materials damage also occurs in the production activities associated with navigation. Damages to navigation arise from the corrosive and abrasive effects of water pollutants on bridges, wharfs, piers, navigation aids, and vessels; damages also result from sedimentation and from floating debris, including pollution-induced growth of algae and weeds.

Survey of Source Studies

Damage estimates for municipal water supplies are derived from U.S. Census Bureau publications (1970 and 1974) which provided treatment costs and water use data. Unger et al. (1974), and Bregman and Lenormand (1966), have developed approximations of the damages to municipal water supplies using assumptions on the costs of removing man-made pollution. Unit treatment costs resulting from pollution followed Bregman and Lenormand's arbitrary assumptions of costs per thousand gallons. Bregman and Lenormand estimated that national damages to municipal water supplies were between $118 million and $1.8 billion. Unger et al. revised Bregman and Lenormand's costs per thousand gallons estimates by the consumer price index and estimated 1974 benefits.

National damage estimates for industrial water uses also were reported by Unger et al. This estimate utilized Bregman and Lenormand's estimate of pollution-related treatment costs per thousand gallons, and industrial water use data for the year of the estimate. As previously noted, Unger et al. applied the consumer price index to Bregman and Lenormand's figures; additionally, Unger et al. extrapolated their best estimate obtained from Bramer (1960).

Agricultural damage estimates have for the most part followed the methodology presented by Unger et al. Using variables relating water quality, cost, and land-use parameters, Unger et al. calculated the direct salinity impact on agriculture. The American Society of Agricultural Engineers was the source of the agricultural damage estimate attributed to sediments. A Dow Chemical Company (1972) study developed regional sediment impact estimates on agriculture.

An irrigation water loss estimate was first reported in Holm, Weldon, and Blackburn (1971). They used Timmons's (1960) estimate of acre-feet of water loss and Wollman et al's (1962) value of an acre-foot of water.

The commercial fishery damage estimates and range are reported by Tihansky (1973), Bale (1971), Weddig (1973), Council on Environmental Quality (1970), and U.S. Environmental Protection Agency (1972).

Studies such as Black and Veatch (1967), Hamner (1964), American Water Works Association (1961), Patterson and Banker (1968), Leeds, Hill, Jewett, Inc. (1969), Metcalf and Eddy (1972), and Williams (1968) were reviewed by Tihansky to derive economic damage functions for household water use. Unger et al. also reported damages from similar sources. Black and Veatch and Metcalf and Eddy were the primary sources employed by Unger et al. Damages are estimated for total dissolved solids and hardness, and the use of bottled water.

Bramer (1972) specifies the damages from acid corrosion which can be attributed to navigation. Other studies which have estimated damages to materials include Ohio River Committee (1943), U.S. Army Crops of Engineers (1969), and Dow Chemical Company.

PROPERTY VALUE DAMAGES

Nature and Effects of Pollution Damages as Reflected in Property Values

The effects of water pollution on the value of water uses have been shown to be also reflected in the value of nearby properties. The water use values that most strongly influence property values are those directly related to ownership of the land, namely recreation, aesthetic enjoyment, and ecological enjoyment. Production activities and health are less dependent on locations directly adjacent to water, and damages in these categories are less strongly reflected in property values. Residential and recreational properties are similarly more affected by water pollution than commercial and industrial properties, except for those commercial activities directly related to water recreation.

A study by Dornbusch and Barrager (1973) included an interview survey of property owners in seven areas where pollution abatement had occurred. The responses indicated that wildlife support capacity is more important to property owners than aesthetics or recreation. The pollutants having strongest damaging effect on fish and wildlife are included in the National Sanitation Foundation's FAWL Index; these are biological oxygen demand, heat, acidity, phenols, turbidity, ammonia, dissolved solids, nitrate and phosphate. The pollutants most strongly affecting aesthetics and recreation as discussed in previous sections include floating debris, oil, odor, clarity, color, and fecal coliform.

SURVEY OF SOURCE STUDIES

The primary study on water pollution and property values was performed under EPA sponsorship by Dornbusch and Barrager. This study applied multiple-regression analysis to determine the relationship between changes in property values as determined by sale prices, and water quality as determined by the EPA Pollution-Duration-Intensity Index. The results from seven case-study areas were extrapolated to provide a national estimate by separately considering metropolitan areas, towns, and rural areas. The estimated capital value of $0.6 to $3.1 billion in 1972 was annualized at a 6 percent discount rate, giving $33 to $175 million per year with a best-estimate of $76 million.

In an earlier study, Nemerow and Faro (1969) showed that property along the shore of Onondaga Lake near Syracuse, N.Y., would increase in value by over $1 million per year if the PDI index were lowered from 5 to 1. David and Lord (1969) found that improvements in water quality on artificial lakes in Wisconsin would increase adjacent property values by 7 percent. In a study of Rocky Mountain National Park, Ericson (1975) found that tourists in Colorado were willing to pay 123 percent more for land that was adjacent to unpolluted waterways. All of these studies confirm the positive relationship between water quality and property value, although the strength of the relationship clearly varies from place-to-place.

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Chapter 3
The Costs of Controlling Water Pollution

1. INTRODUCTION

Scope

This section of the report presents national level estimates of the costs of meeting the provisions of the Federal Water Pollution Control Act amendments (P.L. 92-500), hereafter referred to as the Act.

Costs reported include those attributable directly to control measures (devices, process changes, etc.) and program costs for research, administration, enforcement at the Federal, state, and local levels. Sources of water pollution are broken down into industrial, municipal, and nonpoint categories, and direct control costs are estimated for these categories.

Industrial costs at the plant level are taken for the most part from the Effluent Guidelines Development Documents, which were prepared under Sections 304, 306, and 307 of PL92-500. These documents define the levels of pollutant removal that must be achieved by each industry category at the interim level, best practicable technology (BPT) to be achieved by July 1, 1977, and the final level, best available technology (BAT) to be achieved by July 1, 1983. Total industry costs are computed by developing plant-level costs for one or more "model" plants of various sizes and process configurations which are typical of those in the industry. The total output of the industry is then attributed to that number of model plants in each size category which best approximates the actual size distribution in the industry. The total cost is then simply the number of model plants in each size category times the plant level costs for that category, summed over all size categories.

Municipal costs are presented as total capital investment achievable under the existing Federal contract authority, (i.e., what will be spent rather than what is needed), as distinguished from the industrial costs, which are estimates of what will be required to achieve given control technology levels. As an indicator of the total requirement for municipal treatment plant construction, results from a 1976 survey of state estimates of construction requirements were taken from "Cost estimates for Construction of Publicly-Owned Wastewater Treatment Facilities," Final Report to the Congress, February 1977.

Assumptions

The highlights of the assumptions made regarding compliance with P.L. 92-500 are listed below. With the exception of municipal treatment, these assumptions reflect full compliance with the technology levels and deadlines included in Federal legislation. In the municipal program, it is recognized that the construction rate will be set by the level of Federal expenditure, i.e., the cost of bringing all plants to at least secondary level treatment by 1977 (or possibly by 1983) is beyond anticipated expenditure levels. The outlay schedule used in the Reference Case was projected using current Federal contract authority; one other outlay schedule is considered as an alternative.

FEDERAL COMPLIANCE ASSUMPTIONS

Industrial. Except for publicly-owned treatment works, BPT must be applied to existing point sources of water pollution by July 1, 1977, or compliance with pretreatment requirements must be met if water is to be diverted to publicly-owned treatment works.

Except for publicly-owned treatment works, the BAT which is economically achievable for each pollutant category must be applied to all point sources of pollution by July 1, 1983, or compliance with pretreatment requirements must be met.

The Effluent Guideline Development Documents for pretreatment, BPT, BAT, and New Source Performance Standards (NSPS) are the source of regulations and costs relating to industrial sources of water pollution.

In some industries, BAT is the same as elimination of discharge (EOD), which is desired by 1985; in others, extreme expense would be incurred to completely eliminate discharge. Since no Federal regulations currently require EOD, it was not considered in the estimation of pollution abatement costs. The aspect of treatment requirements above BPT in water-quality-limited stream segments, as per Section 301 of the Act, is not addressed in this analysis. This could result in a very slight underestimate of costs in the 1976-85 period.

Municipal. According to the Act, publicly-owned treatment works in existence in July 1, 1977, or approved under the act, must meet secondary effluent limitations by July 1, 1977 (or ambient water quality standards, if they are more stringent). However, the Reference Case assumption in this report is that treatment plants will be built only at the rate allowed for by Federal appropriations and state matching funds as shown in Table 1-1.

Table 1-1.
Projected Outlays Under Current Contract Authority
(In Millions of 1976 Dollars)

FY	Direct Capital Outlays (Fed., State, Local)	FY	Direct Capital Outlays (Fed., State, Local)
1975	2,773	1980	2,833
1976	3,628	1981	1,010
Transition	1,280	1982	598
1977	5,623	1983	251
1978	6,837	1984	251
1979	5,558	1985	251

The entries in Table 1-1 consist of Federal funds from P.L. 84-660, P.L. 92-500, P.L. 94-447, and P.L. 95-26. State and local matching funds are 60 percent for P.L. 84-660 funds and 25 percent for all other authorizations.

The Act requires that by July 1, 1977, all publicly owned treatment plants should achieve effluent limitations based on secondary treatment as defined by EPA, and that by July 1, 1985, all plants should achieve Best Practicable Waste Treatment Technology (BPWTT) (or ambient water quality standards, if they are more stringent). EPA's 'Water Programs-Secondary Treatment Information' (40 CFR Part 133) is the source of regulations which define the secondary treatment effluent levels. For this analysis, BPWTT is regarded as the same as meeting secondary treatment standards.

Pollutants

A complete description of water quality has never been accomplished, primarily because it would require chemical analysis of a near-infinite number of solid, liquid and gaseous compounds, as well as the identification of numerous biota also present in water. Thus, any practicable description of water quality can only be conceived with a very limited subset of all conceivable physical, chemical, and biological aspects of actual waterbodies. Typical water quality measurements are, in fact, oriented toward a small group of commonly-observed pollution problems.

The most common pollutants (or pollutant groups) are discussed in the following paragraphs. There are some other pollutants which are subject to effluent limitations, but they are found in the waste streams of a very small number of plants; these are covered in the industry summaries in this chapter.

BIOCHEMICAL OXYGEN DEMAND

Biochemical oxygen demand (BOD) is a measure of the oxygen-consuming capabilities of organic matter; this matter is the traditional organic wastes and ammonia contributed by domestic sewage and industrial wastes of plant and animal origin. Besides human sewage, such wastes result from food processing, paper mill production, tanning, and other manufacturing processes. The BOD does not, in itself, cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Conditions are sometimes reached where all of the oxygen is exhausted, and the continuing anaerobic decay process causes production of noxious gases, such as hydrogen sulfide and methane. In addition, since fish and plant life depend on oxygen for life, failure to control the oxygen-demanding wastes will kill the fish.

Chemical oxygen demand (COD) is another measure of oxygen-consuming pollutants in water. COD differs from BOD, however, in that COD is a measure of the total oxidizable carbon in the waste, and related to the chemically-bound sources of oxygen in the water (i.e., nitrate which is chemically expressed as NO_3) as opposed to the dissolved oxygen.

SUSPENDED SOLIDS

Suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, animal and vegetable fats, various fibers, sawdust, hair, and various materials from sewers. Some of these solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the stream or lake with a blanket of material that destroys the fish-food bottom fauna or the spawning ground.

While in suspension, these solids increase the turbidity of the water, reduce light penetration, and impair the photosynthetic activity of aquatic plants.

DISSOLVED SOLIDS

Total dissolved salts represent the residue (exclusive of total suspended solids) after evaporation, and they include soluble salts, such as sulfates and chlorides, and possibly nitrates of calcium, magnesium, sodium, and potassium, with traces of iron, manganese and other substances. Excessive levels of dissolved salts can make water unfit for drinking and irrigation purposes.

Total dissolved solids are particularly significant as a pollutant in discharges from closed systems which involve water recirculation and reuse. These systems tend to concentrate dissolved solids as a result of evaporation and require blowdown (continuous removal of a small amount of the recirculating water) to maintain dissolved solids within acceptable limits.

NUTRIENTS

Nutrients are substances that support and stimulate aquatic plant life, such as algae and water weeds. Carbon, nitrogen, and phosphous are the chief nutrients present in natural water. Large amounts of these nutrients are produced by sewage, certain industrial wastes, and drainage from fertilized lands. Biological waste treatment processes do not remove the phosphorus and nitrogen to any substantial extent. In fact, they convert the organic forms of these substances into mineral form, making them more usable by plant life. The problem starts when an excess of these nutrients over-stimulates the growth of water plants, causing unsightly conditions, interfering with treatment processes, and causing unpleasant and disagreeable tastes and odors in the water.

pH,ACIDITY, AND ALKALINITY

Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions by hydrolysis, and alkalinity is produced by substances that yield hydroxyl ions; pH is a logarithmic measure of the number of hydrogen ions present. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Waters with a pH above or below 7.0

can be corrosive to waterworks structures, distribution lines, etc.

Water Pollutant Controls

The control of water pollution involves a wide variety of methods designed to reduce the flow of pollutants into the nation's waterways. The methods employed differ considerably from location-to-location, depending primarily upon the types of pollutants present, the desired level of treatment, the climate, and the quality and quantity of land available.

THE TOTAL WATER POLLUTION CONTROL SYSTEM

A well-designed water pollution control system minimizes the volume and level of pollution of water that must be treated, produces the desired degree of purity in the water discharged, and properly disposes of the residual sludges. The four general categories of control which comprise the total water pollution control system are described below.

In-Process Controls. In-process controls are methods designed to reduce water use and prevent the introduction of pollutants into the water used. These methods are particularly important in industry where changes in the production processes, the use of raw materials, and the flow of process waters can significantly reduce the volume and degree of pollution of the wastewater streams.

Collection System. Before treatment, the wastewaters must be collected and channeled to the treatment plant. The collection systems of municipal treatment plants, the city sewer systems, represent a considerable portion of the municipal investment (approximately 55 percent) in water pollution control. Proper maintenance and prevention of leaks in these systems can significantly reduce the wastewater flow into municipal treatment plants.

Wastewater Treatment. The actual treatment of polluted waters is designed through a wide variety of methods which are discussed in subsequent paragraphs.

Sludge Disposal. The pollutants removed from the wastewater must be disposed of properly so that they do not return to the waterways. The most common methods of sludge disposal are sanitary landfill, incineration, and land spreading.

WASTEWATER TREATMENT SYSTEMS

The heart of any water pollution control system is the wastewater treatment system which takes in wastewater, removes pollutants, and discharges purified water. Wastewater treatment systems consist of a number of components designed to remove different types of pollutants at different stages of the treatment process. Table 1-2 presents a summary of the most common wastewater treatment processes, the types of pollutants they are designed to remove, and the level of treatment most often attained. The treatment systems are often categorized into the three general types described below.

Table 1-2.
Common Wastewater Treatment Processes

TYPE	NAME	DESCRIPTION	POLLUTANTS REMOVED	LEVEL OF EXPECTED TREATMENT
PHYSICAL-CHEMICAL				
Pretreatment	Screening	Screens trap large particles.	SS	Removes large suspended solids
Pretreatment	Equalization	Holding ponds equalize the flow of wastewater to the treatment plant.	-	
Pretreatment	Neutralization	Chemicals added to neutralize acidity or alkalinity.	-	pH 6.5-8.5
Pretreatment	Oil Separation	Oil skimmed off surface.	Oil	Removes particles > 0.015 cm in diameter
Primary	Sedimentation	Wastewater is detained in a holding tank so that suspended solids can settle out.	SS, BOD	30 mg/l - but depends upon influent
Primary	Flotation	Air bubbles bring the suspended solids to the surface where they are skimmed off.	SS, BOD	30 mg/l - but depends on influent
Tertiary or Advanced	Chemical precipitation or coagulation	The addition of chemicals to the wastewater causes metals, etc. to settle out.	Metals, Phosphorous	< 5 mg/l
Tertiary or Advanced	Filtration	Fine media such as earth sand, etc., are used to filter out very fine particles.	SS	5-10 mg/l

Table 1-2. (Continued)
Common Wastewater Treatment Processes

Tertiary or Advanced	Carbon absorbtion	Wastewater is passed over powdered carbon which absorbs organic materials.	COD, TOC	10 mg/l 2 mg/l
Tertiary or Advanced	Ion exchange and electrodialysis	Employs ionic resins or electric current to remove charged particles.	Metals,TOS,dissolved phophorous, nitrogen	Depends on resin used and pollutants present
Tertiary or Advanced	Reverse osmosis	Wastewater is passed through a suitable membrane under pressure.	Organics and Inorganics	?
Tertiary or Advanced	Air stripping	Air is passed through wastewater, pH has been adjusted by the addition of lime.	Ammonia	95% removal
		BIOLOGICAL		
Secondary	Trickling filter	Wastewater is passed over bacteria growing on a bed of rocks.	BOD	? < 50 mg/l
Secondary	Aerated lagoons	Air is pumped into the wastewater to aid the bacteria's digestion of organic wastes.	BOD	< 50 mg/l
Secondary	Stabilization Ponds	Digestion allowed to occur in ponds without the addition of air.	BOD	? < 50 mg/l
Secondary	Anaerobic ponds	Uses a fermentation process to digest organic wastes.	BOD	> 100 mg/l

Table 1-2. (Continued)
Common Wastewater Treatment Processes

Secondary	Activated sludge	Recycles bacteria-laden sludge to accelerate digestion of organic materials.	BOD	< 25 mg/l
Tertiary or Advanced	Nitrification/ denitrification	Two-stage process with aeration and sludge organisms.	Nitrogen	< 5 mg/l
		LAND TREATMENT		
Secondary and Tertiary or Advanced	Irrigation or spray irrigation	Wastewater is applied to the land which acts as a natural filter	Organic and Inorganics	Up to 100% removal

Physical-Chemical. These processes rely primarily upon physical means, such as skimming, screening, or gravity settling; and chemical processes, such as neutralization, chemical precipitation, carbon absorbtion, or ion exchange.

Biological. The biological processes employ bacteria to digest organic pollutants in the wastewater, after which the bacteria are removed primarily by physical means. Commonly-used biological systems include trickling filters, lagoons, and activated sludge plants. In trickling filters, bacteria are grown upon a bed of stones 3-to 10-feet deep. When wastewater is passed over these stones, the bacteria are able to consume most of the organic materials present. Where more land is available, lagoons are employed to allow the sunlight, oxygen, and algae to interact and restore the water naturally. Lagoons may be anaerobic, aerobic, or aerated depending upon how much oxygen is required. Activated sludge plants are more advanced systems in which the process or biological digestion is accelerated by bringing air and sludge heavily-laden with bacteria into close contact with the organic wastes. Septic tanks are smaller-scale biological treatment systems commonly employed for individual residences.

Land Treatment. These processes allow pretreated wastewaters to percolate through the soil; organic and inorganic wastes are then removed by this natural filter. Irrigation and spray irrigation are common methods of land treatment which are often used to enhance agricultural production.

STAGES OF TREATMENT

Each wastewater treatment system is comprised of a number of components arranged in sequence so that finer and finer levels of treatment are achieved. The components used and the treatment required vary widely from system to system; however, four generally-accepted stages of the treatment process are discussed below.

Pretreatment. To prepare the wastewater for further on-site treatment or for discharge to a municipal treatment plant, suspended solids and oils are removed by skimming or screening, acidity or alkalinity is reduced by chemical neutralization, and the flow of wastewater is often equalized through the use of storage ponds. Heavy metals or toxic materials might also be removed at this stage.

Primary Treatment. After pretreatment, the wastewater is generally allowed to remain for some time in sedimentation tanks so that most of the remaining suspended material allowed to settle out. Flotation devices might al employed to remove suspended solids in the primary treatment stage.

Secondary Treatment. Secondary treatment generally consists of biological treatment processes designed to remove the organic wastes that have not settled out of the wastewater. Further sedimentation may then be necessary to remove the bacteria generated by the biological treatment.

Tertiary or Advanced Treatment. In the advanced treatment processes, many remaining pollutants are removed by very specialized treatment processes designed to remove specific chemicals, nutrients, metals, etc. Before being introduced into the waterways, the water is often chlorinated to kill any harmful bacteria that might be present.

NONPOINT SOURCE WATER POLLUTION CONTROL

The above discussion has dealt primarily with wastewater treatment systems designed to treat "point sources" of pollution; i.e., wastewaters which are channeled through a pipe. A significant amount of soils, nutrients, and other pollutants are introduced into the waterways from the run-off of rainwater from fields, city streets, etc., which are classified as "nonpoint sources" of water pollution.

The control of nonpoint source pollution does not involve treatment systems as sophisticated as those discussed above. Usually, nonpoint sources can be controlled to some extent by correct soil conservation practices, the planting of grass and other vegetation, and when necessary, the provision of settling ponds or sedimentation basins. Considerable research is underway to develop dependable information for designing nonpoint-source controls. However, the level of controls to be applied nationally and the best implementation strategy are still not sufficiently defined to warrant cost estimation for agricultural nonpoint sources.

2. GOVERNMENT EXPENDITURES FOR WATER POLLUTION CONTROL

Government funds for water pollution control are spent for three major purposes:

- To conduct programs of monitoring, enforcement, technical assistance, grant assistance, and research,
- To abate pollution created at government-owned facilities, and
- To treat wastewater at municipal treatment facilities.

Generally, states have primary responsibility for monitoring and enforcement with financial and other assistance provided by the Federal government; research is conducted primarily by the Federal government, and treatment of municipal wastewater is the responsibility of local and state governments with major financial assistance from the Federal and state governments.

This discussion centers on the general program of Federal and state governments, and it projects their respective program costs over a 10-year period; it also includes estimates of the cost of abating pollution at Federal facilities. Details of the analysis are not presented here since the main purpose of this effort is to determine the magnitude of this category of expenditure relation to other expenditures in the report.

PROGRAM COSTS

Federal and state program costs are summarized in Table 2-1. Federal expenditures (exclusive of construction grants and grants to states) are projected to decrease from the 1975 level of $326 million to $187 million in 1978. The Federal share of program expenditures is also projected to decline over the forecast period as the states gradually assume greater responsibility in implementing the programs and regulations. Total decade expenditures for this category are projected at 3,174 million.

Table 2-1.
Projected State and Federal Program Costs

Costs per Fiscal Year[1]
(In Millions of 1973 Dollars)

	1976	Tran-sition[3]	1977	1978	1979	1980	1981	1982	1983	1984	1985	Total
Federal[2]	211	41	215	187	187	187	162	162	162	162	162	1842
State	130	33	130	130	130	130	130	130	130	130	130	1333
Totals	341	74	345	317	317	317	292	292	292	292	292	3174

[1] Excludes Construction Grant funds which are included in the Municipal Cost section.
[2] Excludes State Program Grant funds which are included in the state totals.
[3] Three-month period July 1 through October 31, 1976, caused by change of Fiscal Year from July 1-June 30, to October 1-September 30.

Federal Program Costs

Federal responsibilities which are exercised primarily through the U.S. Environmental Protection Agency (EPA), encompass a broad range of authorities, particularly since enactment of the Federal Water Pollution Control Act Amendments of 1972. On the one hand, they encourage compliance through grants and other types of assistance; on the other, they require compliance through regulatory programs.

ASSISTANCE PROGRAMS

EPA conducts several assistance programs, including the grants for wastewater treatment works, grants for regional water quality planning, program development, technical assistance, and manpower development.

The construction grants program is by far the largest, involving $2 billion in Federal funds in fiscal year 1973, $3 billion in 1974, $4 billion in 1975 and $9 billion in 1978. The level of assistance has gradually increased since the first permanent Federal pollution control legislation was enacted in 1956; today, the Federal share is 75 percent of project capital costs. A variety of projects are eligible for funding, including treatment plants and interceptor sewers. Details of this category of expenditures are presented in the next chapter.

EPA also provides program grants to assist the states, interstate and regional agencies expand and improve a variety of activities essential to the control of water pollution. The activities include water quality planning and standards setting, surveillance, enforcement, issuance of permits, executive management, and administration of the construction grants program. The level of assistance varies from one activity to another, as well as from year to year. In 1975 and 1976 over $200 million dollars was granted to regional agencies for areawide waste treatment management plants. However, in the future, funding for this program will drop to a low maintenance level for the next few years.

The feasibility of a new consolidated grants program is currently under study by the Agency which would combine the state assistance programs for water quality, air quality, water supply and solid waste. If such a program were initiated, the Abatement and Control category in Table 2-2 would drop by an amount roughly equal to the water quality state assistance program. Since allocation of these consolidated funds among the four categories might become a state option, forecasting future water quality expenditures would require additional analysis.

Technical assistance is another program receiving major EPA attention. Many pollution problems are too complex for states, communities, and industries to handle alone. EPA assists in such cases by providing services ranging from technical advice and consultation to extensive, long-term field and laboratory studies. Within the limits of available resources, this assistance is provided on request, primarily to the states and municipalities.

As might be expected, the rapid expansion of pollution control activities has placed a strain upon the supply of trained manpower. In providing assistance, EPA pursues a number of approaches; these include providing short-term training by EPA staff to upgrade the skills of those already in the field, and employing a variety of ways to train sewage treatment plant operators.

REGULATORY PROGRAMS

To facilitate enforcement of the many new pollution control requirements, the 1972 Act replaced former enforcement authorities with new authorities and provided a new regulatory scheme based largely on the imposition of specific requirements through a system of permits and termed the National Pollutant Discharge Elimination System (NPDES). Permit conditions and other requirements of the Act are enforceable through EPA compliance orders and civil suits; violators are subject to penalties. A state may assume the responsibility if it meets certain requirements, including the capability and authority to modify, suspend, or revoke a permit, and it has the powers and procedures necessary for criminal penalties, injunctive relief, and other enforcement mechanisms.

The Act also required Federal agencies to comply with Federal, state, interstate, and local pollution control and abatement requirements to the same extent as any person must comply. EPA's role stems from the Act and is amplified in Executive Order 11752. The role includes review of Federal facilities compliance with applicable standards, providing guidance to the Federal agencies for implementing provisions of the Order, providing coordination of Federal agencies' compliance actions with state and local agencies, and providing technical advice on waste treatment technology.

Table 2-2 projects a stabilized Federal water quality program beyond FY78, reflecting the need for Federal fiscal restraints and the gradual acceptance of greater environmental responsibilities by the states. Water quality program expenditures are usually divided into three categories: abatement and control covers the numerous management and assistance activities of the water quality program, research and development provides the scientific and technical support for the program, and enforcement covers actions seeking compliance with the law. Table 2-2 shows projected Federal program expenditures according to the three categories listed.

Table 2-2.
Projected Federal Water Quality Program Expenditures

Fiscal Year Expenditures
(In Millions of Dollars)

	1976	Tran- sition	1977	1978	1979	1980	1981	1982	1983	1984	1985	Total
Abatement and Control	145	25	153	150	150	150	150	150	150	150	150	1523
Research and Development	45	11	44	44	45	45	45	45	45	45	45	459
Enforcement	21	5	21	21	21	21	21	21	21	21	21	215
Totals	211	41	218	216	216	216	216	216	216	216	216	2197

State Program Costs

STATE ROLE

Although the Federal government has taken an increasingly greater hand in dealing with water pollution, the states continue to bear the major share of the responsibility. States inherently have broad powers to deal with water pollution, and these powers, together with delegated Federal authorities, place the states in a strong position to regulate all sources of pollution. State powers and responsibilities under the Act are exercised through a broad range of activities, including:

- States prepare an annual strategy and program report that describes the interim goals to be achieved during the year, the state resources to be assigned in meeting the goals, and the method of assigning resources.

- States prepare basin water quality management plans, as required by Section 303(e) of the 1972 Act. These plans are designed to be the central management tools of the states in administering their water quality programs.

- States are responsible for reviewing areawide waste treatment management plans called for by Section 208 and prepared by local agencies.

- States have major responsibilities in the administration of the construction grants program, including the responsibility for assigning priorities to projects eligible for Federal financial assistance. It is intended that certain Federal responsibilities, such as review of plans and specifications, be transferred to the states as they are able to assume them. Some states provide funds to assist communities in constructing waste treatment works. Primary responsibility for monitoring municipal treatment plants to see that they operate correctly also rests with the states.

- States have the basic responsibility for planning and implementing programs for control of nonpoint sources of pollution.

- Some states have assumed, and others are in the process of assuming, responsibility for the NPDES permit program. States that have received the responsibility have concurrently assumed extensive enforcement responsibilities associated with permit compliance.

- States and the Federal government share responsibility for enforcement.

- States establish and implement water quality standards. Under the 1972 Act, such standards are extended to intrastate, as well as interstate, waters.

- States perform monitoring and surveillance functions to identify and assess existing and potential water pollution problems, and also to measure the effectiveness of the permit and construction grants programs.

AGGREGATE STATE PROGRAM EXPENDITURES

Methods for estimating state program costs are discussed in Section 1. As shown in Table 2-1, state program expenditures are expected to remain level at about $130 million per year. Within this stable budget expenditure will gradually shift from planning to enforcement. The assumptions behind the analysis suggests a continuation of activity in almost every area. Revisions of water quality standards, issuance of a new round of permits, compliance and ambient monitoring and construction grant review, in fact, may require the maintenance of state programs at a higher expenditure level than projected. However, anticipated revenue constraints at the State and Federal level combined with competing social needs lend credence to a level projection.

Expenditures by Other Federal Agencies

The following information is excerpted and adapted from: Office of Management and Budget, "Special Analyses: Budget of the United States Government," USGPO, 1976.

Although covering a wide range of activities, Federal environmental programs are classified in three broad categories: pollution control and abatement; understanding, describing and predicting the environment, and environmental protection and enhancement activities. It is difficult to attribute non-EPA Federal expenditures to specific pollution control legislation in many cases, but an approximation of P.L. 92-500 related expenditures is given by the water quality expenditures in the Pollution Control and Abatement category. Principal activities in this category include actions necessary to reduce pollution from Federal facilities; the establishment and enforcement of standards; research and dvelopment; and the identification of pollutants, their sources, and their impact on health. Non-EPA water quality expenditures by the Federal government in FY1976, the transition quarter and FY1977 are 527, 83, and 467, million dollars respectively.

Since Federal spending is strongly influenced by policy and competing social needs, forecasting is always problematical. The best estimate currently is that such expenditures will remain stable over the next several years, with only minor growth or decline. If non-EPA Federal outlays in this category were to be held constant at the FY1977 level, total decade expenditures would be about 4.8 billion dollars. While this is a large amount on an absolute basis, it is relatively small compared to total expenses in the nation for P.L. 92-500.

3. MUNICIPAL CONTROL COSTS

Introduction

The 1972 amendments to the Clean Water Act established technology objectives and water quality objectives for controlling pollution from municipal sources. The technology objectives require that all publicly-owned treatment works install" best practicable wastewater treatment technology" (BPWTT). Provision for BPWTT requires a complete evaluation, on a case-by-case basis, of (1) conventional treatment and discharge to surface waters, (2) land application of wastewater, and (3) reuse technologies. As a minimum, either secondary treatment (85 percent control organic and suspended solids and a pH between 6.0 and 9.0) or higher levels of treatment as required to meet water quality standards must be provided. These standards are based on achieving a level of water quality that will provide for the protection and propagation of fish, shellfish, and wildlife, and will provide for recreation in and on the water. This section reports the costs associated with meeting these dual objectives.

DEFINING AND MEASURING NEED

The 1976 Needs Survey conducted in compliance with Section 516 (b) (2) of the Act, estimates the expenditures required to meet the technology and water quality standards and to provide for replacement or expansion of facilities as necessary to serve the population projected to 1990. Thus, a "need" consists of the resources associated with the upgrading, replacement, expansion or construction of treatment facilities which state or local governments consider to be necessary, based upon the Federal standards.

The Needs Survey is conducted independent from the comprehensive analysis, and details may be found in a separate report "Cost Estimates for Construction of Publicly-Owned Wastewater Treatment Facilities-1976 Needs Survey," EPA-430/9-76-010.

DEFINING COST

While all other sections of the report estimate costs for compliance with effluent or emission standards, several complications preclude presenting that type of analysis in this case. Because of the difficulty facing municipalities in raising capital, and limitations in Federal construction grants, treatment plants cannot be built fast enough to assure compliance with the Act. Instead, it is assumed in this report that new plants will only be built as rapidly as permitted by Federal appropriations and state and local matching funds. The total investments shown in Table 3-8 are composed of Federal outlay estimates for the given year, plus required state and local matching funds.

Not all costs reported herein are properly attributable to the standards created under the authority of P.L. 92-500. The costs attributable to those standards are incremental; only those costs associated with going from an existing level of treatment to a higher level of treatment necessary to meet technology and water quality objectives are properly attributable to the standards. Thus, costs for replacement of facilities built prior to 1972 which do not require a different level of treatment, the cost associated with the lower level of treatment that would otherwise have been achieved in facilities built after 1972, and the cost associated with a higher level of treatment than is necessary to meet the standards should be excluded from the costs attributed to meeting standards. However, since Section 516(b) directs assessment of the costs of "carrying out the provisions of the Act," and the construction grant program is an integral part of the Act, the entire range of costs attributed to that program are reported herein.

The concept of cost employed in this report is that of cost to society, not financial cost. Hence, the interest rate applied in the annualization of investment cost (10 percent) does not represent the cost of borrowing funds in the municipal bond market; rather, it represents the opportunity cost of applying to the public sector those funds which might otherwise be yielding a competitive return in the private sector.

STATUS OF PUBLIC SEWERAGE

Since 1940, the nation's public sewerage treatment systems have improved dramatically through expansions in the scope of their coverage and in their capabilities for treatment, but the systems have not kept pace with the amount of residuals to be processed. The coverage of the systems has kept pace with population growth and expanded to encompass parts of the population previously not served. Between 1940 and 1974, U.S. population increased by 37 percent; the population served by sewers increased 385 percent, and the population served by treatment facilities increased by 337 percent. As Table 3-1 indicates, approximately 73 percent of the population was served by sewers and 92 percent of the sewered population was served by treatment facilities by 1976.

The capability of the systems to treat waste has improved as well. In the same period, the number of persons whose wastes receive primary treatment (physical processes that remove roughly 30 percent of solids and about 35 percent of BOD$_5$) had tripled. The population employing at least secondary treatment (biological processes that raise the removal of BOD$_5$ and solids to the 70 to 85 percent level) increased more than fourfold, and now includes about 50 percent of the sewered population. Not only have more persons been connected to more advanced types of sewerage treatment facilities, but technological modifications have improved the removal efficiencies of each type. (see Table 3-2).

Table 3-1.
Degree of Sewage Treatment

Population Served by Sewerage (In Millions)

Year	No Treatment	Less Than Secondary Treatment	Secondary Treatment[1]	Greater Than Secondary Treatment
1940	29.9	15.1	18.9	--
1945	27.9	17.2	21.7	--
1948	28.0	18.4	22.7	--
1957	23.8	25.7	43.3	--
1962	17.0	32.7	61.2	--
1968	10.9	36.9	85.6	0.3
1974	3.2	54.6	105.0	2.7
1976[2]	15.7	45.2	35.2	50.5

Sources: Engineering News Record, survey of municipalities 1940-74; EPA and predecessor agencies in "Municipal Waste Inventories", 1976 Needs Survey.

[1] Plants employing secondary-type technology; they may not meet current definitions of secondary effluent standards.

[2] 1976 figures were not incorporated into the overall cost estimates.

Table 3-2.
Effect of Sanitary Sewage Treatment

(Millions of pounds of BOD5 per day)

Year	Collected by Sanitary Sewers[1]	Reduced by Treatment[2]	Discharged by Treatment Plants
1957	16.4	7.7	8.7
1962	19.8	10.8	9.0
1968	23.3	15.0	8.3
1974	27.6	18.5	9.1
1976[3]	41.8	31.8	10.0

[1] Based on 0.167 of BOD5 per sewered person per day.

[2] Based on the distribution of treatment facilities shown in Table 3-1 and on estimates of removal efficiency from a variety of sources.

[3] 1976 figures were not incorporated into the overall cost estimates.

Although the coverage and treatment capability of the systems have increased, the systems have not kept pace with the increasing volume of residuals to be removed. While one portion of the system, the treatment facilities, increased the amount of BOD_5 diverted from our waterways, another portion, sanitary sewers, more than offset that improvement by delivering more BOD_5 for treatment. These figures may be overly pessimistic as they pertain to sanitary sewerage only; they do not reflect the net result of initiating public treatment for a large (but unknown) number of industrial facilities that previously discharged directly into our waterways. On the other hand, they do not take into account the increased concentration of wastes in sanitary sewerage resulting from such innovations as kitchen garbage disposals.

Although expenditures in the past two decades have significantly expanded the capital stock of public sewerage facilities, the prospect for future decades is that replacement expenditures may consume larger proportions of the annual investment in sewerage facilities. Between 1855 and 1973, the nation invested an estimated $61.8 billion (1972 dollars) in its public sewerage facilities (see Table 3-3); this investment represents about 5 percent of the total state and local government capital expenditures for all purposes since 1915 and resulted in approximately $34 billion worth of facilities in place by 1971. The replacement costs shown here represent an upper bound since they are based on conservative lifetimes of 50 and 25 years for sewers and treatment plants, respectively.

Table 3-3.
Investment in Public Sewerage Facilities

(Billions of 1972 dollars)

Period	Gross Investment[1]	Replacement[2]	Net Investment	End of Period Capitalization
1856-69	$ 0.5	$ 0.1	$ 0.4	$ 0.4
1870-79	0.6	0.1	0.5	0.9
1880-89	0.8	0.2	0.6	1.5
1890-99	1.2	0.4	0.8	2.3
1900-09	1.5	0.6	0.9	3.2
1910-19	2.7	0.9	1.8	5.0
1920-29	5.7	1.6	4.1	9.1
1930-34	2.5	1.3	1.2	10.3
1935-39	4.8	1.6	3.2	13.5
1940-45	2.1	2.3	(0.2)	13.3
1946-56	10.8	5.1	5.7	19.0
1957-61	7.5	3.2	4.3	23.3
1962-67	9.1	4.8	4.3	27.6
1968-73	12.0	5.4	6.6	34.2
Totals	$ 61.8	$ 27.6	$ 34.2	

[1] Based on data published by the Department of Commerce and by EPA; all values converted to 1972 dollars through use of EPA's sewerage construction cost indices and the discontinued Associated General Contractor's Index of Construction Costs.

[2] Estimated funds required to "replace" existing facilities, rather than add new capacity. Computed at a rate of 2 percent for sewers and 4 percent for plants, based on estimates of the relative weight of each in each period.

Two aspects of this series of investments stand out. First, the bulk of sewerage capital has been installed very recently; almost 80 percent since 1929, 60 percent since World War II, and more than 30 percent since 1961. Second, the stock of capital in place is so large compared to annual investments that replacement of existing facilities has absorbed approximately 50 percent of all capital expenditures since 1961. The current level of replacement costs is close to $1 billion a year and rising in proportion to the growth of the capital stock.

Needs Survey Summary

Although the needs survey data are not used directly in preparation of the comprehensive national cost estimates, they do provide essential background for comparison with actual estimated expenditures which are strongly influenced by Federal subsidies. In this interest, the 1976 Needs Survey is summarized below.

CATEGORIES OF NEED

The state estimates of the cost of constructing publicly-owned treatment works needed to meet the 1983 goals of the Act, while serving a projected 1990 population, are divided into six major categories:

Category I. This includes the costs of facilities which would provide a legally-required level of secondary treatment, or best practicable wastewater treatment technology (BPWTT). For the purpose of the survey, BPWTT and secondary treatment were considered synonymous.

Category II. Costs reported in this category are for treatment facilities that must achieve more stringent levels of treatment. This requirement exists where water quality standards require removal of such pollutants as phosphorous, ammonia, nitrates, or organic substances.

Category IIIA. These costs are for correction of sewer system infiltration/inflow problems. Costs could also be reported for a preliminary sewer system analysis and for the more detailed Sewer System Evaluation Survey.

Category IIIB. Requirements for replacement and/or major rehabilitation of existing sewage collection systems are reported in this category. Costs were to be reported if the corrective actions were necessary to the total integrity of the system. Major rehabilitation is considered extensive repair of existing sewers beyond the scope of normal maintenance programs.

Category IVA. This Category consists of costs for construction of collector sewer systems designed to collect sewage and/or correct violations caused by discharge of untreated wastewater into receiving water, seepage to waters from septic tanks and the like, and/or to comply with Federal, State or local regulations and special actions.

Category IVB. This Category consists of costs of new interceptor sewers and pumping stations necessary for the bulk transport of wastewater to treatment facilities.

Category V. Costs reported for this category are to prevent periodic bypassing of untreated wastes from combined sewers to an extent violating water quality standards or effluent limitations. It does not include treatment and/or control of stormwaters.

Category VI. Stormwaters". This includes the costs of abating pollution from stormwater run-off channelled through sewers and other conveyances used only for such run-off. The costs of abating pollution from stormwaters channelled through combined sewers which also carry sewage are included in Category V.

RESULTS OF THE SURVEY

The results of the 1976 survey are presented in Table 3-4 in aggregate national totals, by category. Various subtotals are presented to give an indication of needs versus priorities. For example, 36 percent of the $150 billion total is required for stormwater control. State-by-state data for the same categories may be found in the aforementioned separate report.

Assessment of Backlog

A new addition to the Survey in 1976 was the assessment of need for present populations (the backlog of need). Needs for Categories I-V present populations are estimated to be $75.1 billion, or 78 percent of the 1990 needs. Note that because of their nature, 1990 Needs for Categories IIIA and IIIB are almost exclusively all backlog needs as well. In addition, because of the limitations of eligibility for Category IVA as detailed in Section 211 of P.L. 92-500 and the Construction Grant Regulations (40 CFR 35.925-13), all of the Category IVA needs for 1990 are theoretically also backlog needs. The differences, therefore, are most graphically illustrated in Categories I, II, and IVB, where backlog needs represent 61 percent of the 1990 needs.

Table 3-4.
Summary Table of National Estimates for Construction of Publicly-Owned Wastewater Treatment Facilities

(Billions of 1976 dollars)

Needs Category		1990 EPA Assessment	Backlog Estimate
I	(Secondary Treatment)	12.955	8.093
II	(More Stringent Treatment)	21.279	11.313
IIIA	(Infiltration/Inflow)	3.017	3.009
IIIB	(Replacement and/or Rehab.)	5.486	5.165
IVA	(New Collector Sewers)	16.979	16.979
IVB	(New Interceptor Sewers)	17.923	12.318
V	(Combined Sewer Overflows)	18.262	18.262
Total I, II, IVB		52.158	31.762
Total I-V		95.902	75.142
VI	(Control of Stormwater)	54.133	34.528
Total I-VI		150.035	109.670

The costs reported for the backlog are sufficient only for facilities necessary to serve the June 1975 populations. They do not include any costs for reserve capacity which would be required by the Act to be included in these facilities for population growth beyond 1975. They also exclude estimates for treatment plants and sewers that were not necessary at all in 1975, but are projected to be necessary for 1990 populations.

PROJECTED NATIONAL INVESTMENTS

Table 3-5 shows the anticipated (in August 1977) year-by-year capital investment for municipal treatment facilities as controlled by Federal grant awards. Some of the funds expended during the period are from grants awarded prior to P.L. 92-500, which were matched by state and local funds averaging about 60 percent of total project costs. The $18 billion from P.L. 92-500, the $480 million from P.L. 94-447, and the $1 billion from P.L. 95-26 require only 25 percent state and local matching funds. These matching funds are included in the totals.

The total investment over the decade of $26.4 billion is seen to be 83 percent of the category I, II, and IVB backlog total needs, but only 35 percent of the category I-V backlog total and 24 percent of the category I-VI backlog total. Therefore, EPA has recommended that the construction grant program be augmented by $4.5 billion per year for the period 1978-1987. If Congress were to authorize and appropriate these funds, the expenditure schedule shown in Table 3-6 would result, with the 1976-85 decade total being $63.3 billion, which exceeds the Category I, II, IVB (highest priority) requirements for 1990 population.

Table 3-5.*
Projected Federal, State, and Local Investment for Sewage Treatment Systems Under Current Authority
(Millions of Dollars)

Fiscal Year		Calendar Year	
1976	3,628	1976	4,499
TQ	1,280	--	--
1977	5,623	1977	5,927
1978	6,837	1978	6,517
1979	5,558	1979	4,877
1980	2,833	1980	2,377
1981	1,010	1981	907
1982	598	1982	511
1983	251	1983	251
1984	251	1984	251
1985	251	1985	251
TOTALS	28,120		26,368

* The numbers in this table are based upon 1974 data. These are the totals that were used in the estimation of total costs that appear in the summary analyses. Table 3-5a contains more recent estimates of the investment costs for sewage treatment systems, based on 1977 data.

TQ = Transition Quarter

Table 3-5a.*
Projected Federal, State, and Local Investment for Sewage Treatment Systems Under Current Authority
(Millions of Dollars)

Fiscal Year		Calendar Year	
1976	3,628	1976	4,215
TQ	1,291	--	--
1977	4,437	1977	4,735
1978	5,631	1978	5,608
1979	5,537	1979	5,116
1980	3,857	1980	3,416
1981	2,097	1981	1,811
1982	955	1982	955
1983	955	1983	955
1984	955	1984	955
1985	955	1985	955
TOTALS	30,299		28,721

* These data were collected in 1977. They represent the latest estimates available. They are not reflected in the total cost estimates in the summary portion of this report. Publication deadlines precluded such inclusion.

TQ = Transition Quarter

Table 3-6*

Projected Federal, State and Local Investment for Sewage Treatment Systems Assuming Increased Funding of $4.5 Billion per Year for Period FY78-87

(Millions of Dollars)

	Fiscal Year		Calendar Year	
	1976	3,638	1976	4,499
	TQ	1,280		---
	1977	5,623	1977	5,983
	1978	7,063	1978	7,083
	1979	7,105	1979	7,059
	1980	6,927	1980	6,735
	1981	6,157	1981	6,227
	1982	6,438	1982	6,438
	1983	6,438	1983	6,438
	1984	6,438	1984	6,438
	1985	6,438	1985	6,438
TOTALS		63,535		63,338

* The numbers in this table are based upon 1974 data. These are the totals that were used in the estimation of total costs that appear in the summary analyses. Table 3-6a contains the more recent estimates of costs based on 1976 data. It was impossible to incorporate the 1976 data into the totals without causing undue delay in the publication of this report.

Table 3-6a*
Projected Federal, State and Local Investment for Sewage Treatment Systems Assuming Increased Funding of $4.5 Billion per Year for Period FY78-FY87
(Millions of Dollars)

	Fiscal Year		Calendar Year	
	1976	3,628	1976	4,215
	TQ	1,292		---
	1977	4,437	1977	4,765
	1978	5,752	1978	5,968
	1979	6,617	1979	6,736
	1980	7,097	1980	7,076
	1981	7,017	1981	6,931
	1982	6,675	1982	6,675
	1983	6,675	1983	6,675
	1984	6,675	1984	6,675
	1985	6,675	1985	6,675
TOTALS		62,540		62,391

* These data were collected in 1977. They represent the latest estimates available. They are not reflected in the total cost estimates in the summary portion of this report. Publication deadlines precluded such inclusion.

TQ = Transition Quarter

Time Phasing and Annualization of Costs

Annual costs are the sum of the annualized capital costs and O&M costs. These annualized capital costs are calculated by amortizing the investment over its economic life at a discount rate of 10 percent. The economic life of treatment plants is assumed to be 25 years and that of interceptor and collector sewers is assumed to be 50 years.

As in the industrial sectors, the total capital-in-place used to calculate annualized capital costs is the cumulative investment beginning with calendar year 1971. The standard capital recovery formula was used to calculate increase annualized costs as a function of new investments.

Annual operation and maintenance costs are estimated as a percent of total capital-in-place. For treatment plants, the value is 7.5 percent, and for sewer investments the value is one percent. The aggregate value varies, depending on the estimated year-by-year expenditures in these two categories.

Results of these analyses are found in Table 3 in the Executive Summary.

4. INDUSTRIAL CONTROL COSTS

Introduction

The extent of water pollution and the costs of treating it vary significantly among industries and among the firms within an industry; therefore, it is important to examine the structure, production methods, sources of pollution, effluent standards, and wastewater control technology for each industry. The following sections of this chapter briefly summarize the relevant characteristics of each industry and report the estimated annual abatement costs attributable to achieving full compliance with the 1977 (BPT) and 1983 (BAT) effluent standards.

[NOTICE: The costs in this report result from analyses using 1975 data on industrial facilities and proposed control technologies. Since that time more detailed studies of particular industries have been completed; in addition, the definition of BAT has been altered owing to concerns about toxic materials in effluents. As a result the control costs which appear in this Section must be viewed as having only historical significance in many instances prior to using these estimates for decision making purposes one should check with the Office of Water Quality Planning and Standards in EPA to assess their currency].

Although 32 industries are summarized in the following sections, this report does not purport to encompass all industries or even all parts of any industry. Only those industries or parts of an industry which have significant pollution problems, or for which effluent guidelines have been defined, are included. In the interest of brevity, only the most significant polluting segments of certain industries have been discussed but costs have been estimated for the entire industry. Footnotes to the cost table following each industry summary will denote the assumptions used in the cost calculations and the industry operations that were evaluated.

Methodology

COST CONCEPTS

Only those costs attributable to standards imposed under P.L. 92-500 have been reported. Not all water pollution control costs are associated with this law; an industry may perform some treatment irrespective of the standards imposed under the legislation; changes in manufacturing processes made on grounds of production efficiency or cost-effectiveness may result in higher levels of effluent control or a reduction in the use of water; and some investments in abatement equipment may have been made prior to the enactment of the law.

The annual investment costs reported herein are not expenditures; they are the amounts of total investment that have been annualized; i.e., a capital recovery factor has been applied to the total capital cost. Hence, in any year the actual capital expenditure would far exceed annual investment cost. (For purposes of feedback to the INFORUM Module, expenditures have been used.)

The costs presented here are incremental. The cost of achieving 1977 Best Practicable Technology (BPT) standards is the cost of going from the level of treatment in the base year to the level of treatment defined as BPT in the effluent guidelines. The cost of achieving Best Available Technology (BAT) is the cost of going from the BPT level of treatment (or if such a level is not specified, the base year level of treatment) to the level of treatment defined as 1983 BAT standard in the effluent guidelines. The cost of achieving New Source Performance Standards (NSPS) is the cost of going from a general industry-wide level of treatment in the base year to the cost of meeting the effluent guideline standards for new sources.

MODELING AN INDUSTRY

The essential estimating technique used in preparing cost estimates was to define certain models or "typical" plants and generalize from these plants to the total industry. Cost sensitive parameters, such as wasteload, water flow, water use efficiency, and treatment-in-place, were defined for model or typical plants in EPA Development Documents. In most cases, the model or typical plant data in these documents were taken from actual plants. Unfortunately, the lack of statistically adequate samples of the plants in most industries render it impossible to know just how "typical" the typical plant is in terms of cost-sensitive parameters.

Industries may be defined in various ways. In general, the classification scheme used in the EPA Development Documents was followed. A problem with any classification scheme arises from the multi-product plant, for example, the petrochemical plant which produces a variety of chemicals. Such a plant may be subject to more than one effluent guideline and may be classified in one of several different categories. An attempt was made to avoid double-counting these plants but no attempt was made to develop costs which adequately reflect the costs of treating residuals generated by all products produced in these plants.

The plants in an industry have various options by which to comply with the water pollution standards. In general they may:

1. Fully treat their effluents.
2. Pretreat their effluents and discharge to a municipal system.
3. Change their manufacturing process to eliminate, recycle or reduce their effluents.

To estimate abatement costs for an industry, it is necessary to know or assume what fraction of plants in an industry take each option. Of course, there is no data as to what proportion of the plants in an industry will take various options. Therefore, judgments were made as to how the industry will behave in this respect. Generally, plants were assumed to take the lower cost option, but in no case were plants assumed to close rather than comply with the standards. Thus, the costs reported for industries where plant closure is a persuasive strategy are overstated.

All industry costs were estimated using cost curves of the standard form $Y=AX$, where Y is total cost, X is a measure of plant size, and the exponent B defines how costs change with changes in plant size.

In some cases, special detailed industry studies, which produced more precise estimates than this simple model, became available after the model calculations were completed. These values are reported along with SEAS-estimated values in the various industrial summaries which follow.

Industry Cost Summaries

Table 4-1 lists the industries in the sequence for which estimates have been developed by SEAS; this sequence is also followed to arrange the Group I industry summaries that are presented in this section. The distinction between Group I and Group II is that Group I industries are considered major polluting industries and Group II industries are considered to be of lesser significance as polluters. Phase I and Phase II refer to the manner in which the EPA Effluent Guidelines Division has subdivided the industries for purposes of developing effluent limitations guidelines.

Generally, the most significant polluting segments of an industry have been included in Phase I. Table 4-1 also lists the Standard Industrial Classification (SIC) code for each industry evaluated by SEAS.

Table 4-1.
Industrial Sector Coverage

Group I	Phase I	Phase II	SIC Number
1. Feedlots	x	*	0211
2. Beet sugar	x	*	2063
3. Cane sugar	x	N	2062
4. Dairy	x	*	2021,2022,2023,2024,2026
5. Fruits and vegetables	x	x	2033
6. Grain mills	x	x	2043,2046
7. Meat processing & Poultry	x	N	2011,2016
8. Seafood	x	x	2091,2092
9. Leather	x	*	3111
10. Textiles	x		225,227,228,2211,2231,2297
11. Builders paper	x	*	2661
12. Pulp and paper	x	x	2621
13. Plywood, hardboard, and wood preserving	x	N	2432
14. Inorganic chemicals	x	P	2812,2816,2819,2873
15. Fertilizer	x	N	2873
16. Organic chemicals	x	P	2818
17. Phosphates	x	N	2874
18. Plastics and synthetics	x	N	2821,2823,2824,3079
19. Petroleum	x	*	2911
20. Rubber	x	N	2822,3011
21. Ferroalloys	x	x	3313
22. Iron and steel	x	P	3312,3315,3316,3317
23. Bauxite	x	*	2819
24. Primary aluminum	x	*	3334
25. Secondary aluminum	x	*	3341
26. Primary & Secondary Copper	*	x	3331,3341
27. Primary lead	*	x	3332
28. Primary zinc	*	x	3333
29. Asbestos	x	x	3293,3293
30. Cement	x	*	3241
31. Fiberglass	x	*	3296
32. Flat glass	x	*	3211
33. Pressed and blown glass	*	x	3221,3229
34. Electroplating	x	N	3471
35. Steam electric power	x	*	4911
36. Soaps and detergents	x	*	2841

Table 4-1. (Continued)
Industrial Sector Coverage

Group II	Phase I	Phase II	SIC Number
Fabricated metal	x	*	34
Machinery	x	*	35
Electric and electronic equipment	x	*	36
Transportation equipment	x	*	37

Key:

x	Complete coverage
*	Not applicable
P	Partial coverage
N	No Coverage

As discussed in the Executive Summary of this report, BPT and BAT effluent guidelines undergo continual revision, as new information and experience are obtained and new administrative and judicial decisions are reached. The estimates contained herein do not purport to be the most precise estimate of projected costs available at press time, but represent a snapshot of conditions, knowledge, and assumptions existing as of 1976. Further, the estimates do not reflect the removal of toxic materials which may be required by BAT regulations revised subsequent to 1976. Current specific industry cost estimates are available through the Agency's Office of Water and Hazardous Materials.

FEEDLOTS INDUSTRY

Production Characteristics and Capacities. Feedlots is a term which applies to many different types of facilities used to raise animals in a "high density" situation. For the purpose of establishing effluent limitations guidelines, the term feedlot has been defined by the following three conditions:

- A high concentration of animals held in a small area for periods of time in conjunction with the production of meat, milk, eggs, and/or breeding stock; and/or the stabling of horses;
- The transportation of feed to the animals for consumption;
- By virtue of the confinement of animals or poultry, the land or area will neither sustain vegetation nor be available for crop or forage production.

The effluent limitations guidelines issued to date (phase I) by the EPA cover feedlots for beef cattle, dairy cattle, swine, chickens, turkeys, sheep, ducks, and horses. A variety of facility types are included within the definition of feedlots; these include: open lots, housed lots, barns with stalls, free stall barns, slotted floor houses, solid concrete floor houses, a variety of poultry houses, and wet lots for ducks containing swimming areas.

Raw materials used in the feedlots industry are simply feed, water, and in some cases, bedding. The production processes are defined by the type of facilities employed, and consist mostly of delivering supplies to the animals and carrying away manure and litter.

Although most of the feedlots are classified as small, the bulk of production for many animals is accounted for by the very large producers. Only 1.4 percent of the fed-cattle feedlots accounted for over 60 percent of 1972 production. Although this concentration is not so dominant in some of the other animal groups, the trend toward larger units of production is common in all segments of the industry.

Many producers have diversified into grain production for direct marketing and production of other livestock and poultry. Some are involved in feed grain production, feed-manufacturing, feeder-cattle production, and/or meat packing.

Ownership of commercial feedlots ranges from sole-proprietorships to corporate farms, including co-operatives. The feedlot operator may own the animals being fed or, particularly in the case of fed-cattle, may custom-feed animals owned by others.

Projections of production capacity through 1983 for the cattle, dairy, and hog segments of the feedlots industry anticipate that the trend is toward fewer numbers of production units but the very large units will continue to increase their output volume. Similar projections are not available for the remaining segments of the feedlots industry. However, the growth of production of major agricultural commodities for the period 1970-85 has been estimated. The percentage changes are as follows: beef and veal (33 percent); pork (13 percent); milk (2 percent); chicken (36 percent); turkey (44 percent); eggs (10 percent); and lamb and mutton (65 percent). In all segments of the feedlots industry, it is anticipated that the trend toward larger feedlots will continue. No growth projections are available for ducks or horses.

Waste Sources and Pollutants. Animal feedlots wastewater originates from two principal sources:

- Rainfall runoff
- Flush or washdown water used to clean animal wastes from pens, stalls, milk center areas, houses, continuous overflow watering systems or similar facilities, spillages, duck swimming areas, washing of animals, dust control, etc.

The amount of wastewater varies considerably, depending upon the way manure, bedding, etc., are stored and handled; in the outdoor feedlots, rainfall and soil characteristics determine wastewater characteristics.

Animal feedlot wastes generally include the following pollutants:

- Bedding or litter (if used) and animal hair or feathers
- Water and milking center wastes
- Spilled feed
- Undigested and partially digested food or feed additives
- Digestive juices

- Biological products of metabolism
- Micro-organisms from the digestive tract
- Cells and cell-debris from the digestive tract
- Residual soil and sand.

The primary discharge constituents of concern for pollution control can be described as organic solids, nutrients, salts, and bacterial contaminants. The following specific pollutant parameters have been identified as being of particular importance: BOD, COD, fecal coliform, total suspended solids, phosphorus, ammonia and other nitrogen forms, and dissolved solids.

With the exception of the duck feedlot subcategory, EPA has concluded that animal feedlots can achieve a BPT level of waste control which prevents the discharge of any wastes into waterways by July 1, 1977, except for overflows due to excessive rainfall or similar unusual climatic events (10-year, 24-hour storm as defined by the National Weather Service). The effluent limitations for discharges from duck feedlots have been set at 0.9 kilogram of BOD5 per day for every 1,000 ducks being fed, and a total viable coliform count less than that recommended by the National Technical Advisory Committee for shellfish-producing waters which is 400 fecal coliform per 100 milliliters. The effluent limitations guidelines for all subcategories effective July 1, 1983 (BAT), and for all new sources (NSPS) are still at no discharge of wastewater pollutants, except for overflows due to rainfalls in excess of the 25-year, 24-hour storm (as defined by the National Weather Service).

Control Technology and Costs. In-process technologies used for the control of wastewaters from animal feedlots include site selection, selection of production methods, water utilization practices, feed formulation and utilization, bedding and litter utilization, and housekeeping procedures; all of these are important in minimizing wastewater flow and pollutants.

The various technologies available for end-of-process treatment may be classified as either partial or complete. Partial technologies are defined as those that produce a product or products which are neither sold or completely utilized on the feedlot. Thus, gasification and incineration of manure are considered partial technologies, because a significant quantity of ash must be disposed of. Lagoons, trickling filters, and other biological systems are classified as partial technologies because the effluent may not be suitable for discharge, and in all cases sludge disposal is necessary. Complete treatment technologies produce a marketable product or a product that can be entirely reused at the feedlot, and which has no appreciable byproducts, residues, or polluted water discharge. The dehydration and sale of manure, for example, is a complete technology. The spreading of animal wastes on land for crop fertilization is also a complete control technology.

The 1977 BPT guidelines for all animal feedlots (except those for ducks), the 1983 BAT, and the NSPS guidelines all assume the use of complete control technology. The BPT guidelines are based on the containment of all contaminated liquid runoff and the application of these liquids, as well as the generated solid wastes, to productive cropland at a rate which will provide moisture and nutrients that can be utilized by the crops. Technologies applicable to BAT guidelines include some of the complete technologies, such as wastelage, oxidation ditch-mixed liquor refeed, and the recycling of wet-lot water for ducks, which are not yet fully available for general use. The BPT guidelines for duck feedlots require the equivalent of primary settling, aeration, secondary settling, and chlorination prior to discharge.

Comprehensive and reliable data are not available on the number of feedlots that will require construction of pollution control facilities to meet the effluent limitations guidelines. It is generally accepted that housed (total confinement) and pasture operations can generally meet the guidelines without new investment or operating cost outlays.

Furthermore, open or partially-open feedlots may be situated so that they are not point-source dischargers. Finally, some feedlots have already installed control facilities which meet the guidelines' requirements. Recent estimates suggest that only 10 to 40 percent of all feedlots will require additional investment for control facilities.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	$49.9
Incremental BPT O&M	$ 4.0

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Principal reasons for differences between these cost estimates and the new data are changes in Feedlot inventory estimates, differences in beef production estimates, and breadth of industry coverage (SEAS considers beef only, while G&P considers small animal production also).

[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-1-1.
Feedlots
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (Million Heads)	11.9	14.6	15.5

Annual Growth Rate Over the Period 1976-1985 = 3.21%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	330.93	385.86	402.43
BOD5	136.32	158.95	165.78
COD	470.96	549.14	572.72
Nutrients	60.20	70.20	73.21
Legislated Controls:			
TSS	82.88	0	0
BOD5	34.14	0	0
COD	117.95	0	0
Nutrients	15.08	0	0

CONTROL COSTS (Million 1975 $)			AGGREGATED OVER	
Investment	1974-77		1978-83	1976-85
Existing Plants				
On-site Treatment	128.28	(BPT)	0.0 (BAT)	65.06
Pretreatment	0.00		0.00	0.00
New Plants	15.92		24.23	46.91
Municipal Investment Recovery	0.00		0.00	0.00
Totals	144.19		24.23	111.97

Table 4-1-1. (Continued)
Feedlots
Industry Data Summary

CONTROL COSTS (Million 1975 $) - Continued	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	18.96	22.14	23.34	202.19[2]
O&M[3]				
On-site Treatment	7.94	9.90	10.51	89.16
Pretreatment	0.0	0.0	0.0	0.0
Totals	7.94	9.90	10.51	89.16
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	26.89	32.05	33.85	291.35

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Feedlots industry includes beef cattle feedlots that use storage lagoons and spray irrigation.

BEET SUGAR INDUSTRY

Production Characteristics and Capacities. There were 52 beet sugar plants owned by 11 companies in 1973. An additional two plants began processing in 1974 and a third began operations in 1975.

The size range is classified according to production capacity, small (2,086 metric tons per day), medium (2,086-3,537 metric tons per day), and large (3,537 metric tons per day).

Typical plant production is estimated to be 3,265 kkg sliced beets per day. The main products from this industry are refined sugar, dried beet pulp (used for animal feed), and molasses.

The beet sugar processing industry is a subcategory of the sugar processing industry. Water is commonly used for six principal purposes: (1) transporting (fluming) of beets to the processing operation, (2) washing beets, (3) processing (extraction of sugar from the beets), (4) transporting beet pulp and lime mud cake waste, (5) condensing vapors from evaporators and crystallization pans, and (6) cooling.

Transporting beets into the plant is accomplished by water flowing in a narrow channel (flume) that removes adhered soil. The beets are then lifted from the flume and spray washed. Flume water accounts for about 50 percent of the total plant water consumption.

Process water is associated with the operations of extracting sugar from the beets. Diffusers draw the raw juice from the beets into a solution which contains 10-15 percent sugar. Exhausted beet pulp is later pressed to remove moisture. This exhausted pulp water is usually recycled back to the diffuser.

Lime mud cake waste results when lime is added to the raw juice and the solution is pumped with carbon dioxide gas, causing calcium carbonate to precipitate. The sludge formed contains suspended impurities from the juice.

Water from barometric condensers is employed in the operation of pan evaporators and crystallizers in the industry. Water is used in large quantities, but the quality is not critical since the source of cooling water comes from wells or streams. Condenser water is usually cooled by some device and recycled for use in the plant.

In addition to the above, about 40 percent of the plants employ the Steffen process to recover additional sugar. Syrup remaining from the above processes is concentrated to form molasses, which is desugared by the Steffen process as a method of sugar recovery. Water is used to dilute the molasses and calcium oxide is added to the solution, causing precipitation. The precipitation process produces the Steffen filtrate and recovered sugar; the filtrate may be directly discharged as a waste or it may be mixed with beet pulp to produce byproducts.

The sugar industry is protected and operates on a quota system (domestic and foreign) established by the Federal Sugar Act of 1948 and amended in July 1962. Under this Act, the total national sugar requirement is projected annually and sales quotas to domestic producers are adjusted accordingly. The Act also includes a provision for the industry to increase its production at a rate of 3 percent annually. Areas of future growth will be along the Red River between northern Minnesota and North Dakota, and the Columbia River Basin.

Waste Sources and Pollutants. The major waste sources stem from the primary production processes. These include: (1) beet transport and washing, (2) processing (extraction of sugar from the beets), (3) carbonation of raw juice, and (4) Steffen processing (for those plants involved in desugaring of molasses). Barometric condensers are also a wastewater source. The primary wastes resulting from the beet sugar processing industry are: flume water, lime mud cake from carbonation process, barometric condenser water, and Steffen process dilution water used to dilute molasses for desugarization.

The basic parameters used in establishing water effluent guidelines to meet BPT are: BOD_5, total suspended solids, pH, fecal coliform, and temperature.

Control Technology and Costs. Presently, 11 of the 52 operating plants are achieving zero discharge of wastewaters to navigable waters. A total of five plants discharge flume and/or condenser water to municipal sewage systems.

Current pollution control technology does not provide a single operation that is completely applicable under all circumstances. The major disposal methods are: reuse of wastes, coagulation, waste retention ponds or lagooning, and irrigation.

BPT and BAT are extensive recycle and reuse of wastewaters within the processing operation with no discharge or controlled discharge of process wastewater pollutants to navigable waters. To implement this level of technology, the following are required:

- Flume waters. Recycling with partial or complete land disposal of excess wastewater. This includes: (1) screening, (2) SS removal and control in the recirculating system, and (3) pH control for minimization of odors, bacterial populations, foaming, and corrosive effects.

- Barometric condenser water. Recycling for condenser or other inplant uses with land disposal of excess condenser water.

- Land disposal of lime mud slurry and/or reuse or recovery.

- Return of pulp press water and other process water to the diffuser.

- Use of continuous diffusers.

- Use of pulp driers.

- Handling all miscellaneous wastes (washings) by subsequent treatment and reuse or land disposal.

- Entrainment control devices on barometric condensers to minimize entrainment.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

	Total	Existing	New
Incremental BPT Investment	$11.5	9.6	1.9
Incremental BPT O&M	$ 0.7	0.6	0.1

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Principal reasons for differences between these cost estimates and the newer data are different assumptions for industry growth, differences in attribution of O&M to federal laws, different assumptions of land costs, different model plant cost assumptions, and different distribution of investment costs over industry.

[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-2-1.
Beet Sugar
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (MT/Day)	173,025.	218,841.	229,725.

Annual Growth Rate Over the Period 1976-1985 = 3.49%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	125.67	156.61	164.12
BOD5	33.46	41.70	43.69
Legislated Controls:			
TSS	31.46	0	0
BOD5	33.50	10.41	0

CONTROL COSTS (Million 1975 $)		AGGREGATED OVER	
Investment	1974-77	1978-83	1976-85
Existing Plants			
On-site Treatment	3.59 (BPT)	0.0 (BAT)	1.66
Pretreatment	0.00	0.00	0.00
New Plants	0.40	8.34	10.03
Municipal Investment Recovery	1.29	10.41	15.30
Totals	5.28	18.75	26.99

Table 4-2-1. (Continued)
Beet Sugar
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	0.52	1.62	1.84	11.68[2]
O&M[3]				
On-site Treatment	4.24	5.69	5.95	50.83
Pretreatment	0.0	0.0	0.0	0.0
Totals	4.24	5.69	5.95	50.83
Municipal Charges				
Investment Recovery	0.58	1.94	1.97	15.30
User Charges[4]	1.01	1.69	1.75	20.87
Totals	1.60	3.63	3.72	36.17
Grand Totals	6.36	10.93	11.51	98.68

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Beet Sugar industry products are refined sugar, dried beet pulp for animal feed, and molasses

CANE SUGAR REFINING INDUSTRY

Production Characteristics and Capacities. There are a total of 24 cane sugar refineries in the continental United States and Hawaii. Of these, 18 are crystalline, 4 are liquid, and 2 are combination crystalline-liquid refineries. Crystalline cane refineries are classified into two size ranges: 172-499 and 635-3,175 metric tons per day of melted sugar, and there is one range for liquid cane sugar refineries: 272-771 metric tons per day of melted sugar.

The cane sugar refining industry consists of two subcategories: (1) crystalline cane sugar refining, and (2) liquid cane sugar refining. Liquid sugar production is essentially the same as crystalline sugar production except that the primary product is not recrystallized.

Raw sugar consists primarily of crystals of sucrose and small percentages of dextrose and levulose, with various impurities such as particles, organic and inorganic salts and micro-organisms. A film of molasses is contained in raw sugar. Crystalline raw sugar is washed to remove part of the molasses film, placed into solution, taken through various purification steps, and finally recrystallized.

The major processes involved in cane sugar refining are: (1) melting, (2) clarification, (3) decolorization, (4) evaporation, (5) crystallization, and (6) finishing. Melting is the first step where raw crystals are put into syrup solution by heating and then fine-screened to remove coarse materials. Clarification is the step where screened melt liquor still containing fine suspended and colloidal matter is treated chemically to form precipitation of organics. Decolorization involves physical absorption of impurities and color using bone char as a primary media to remove color. Evaporation consists of concentration of the decolorized sugar liquor and sweet water in continuous type evaporators. Crystallization of the concentrated sugar liquor and sweet waters occurs in batch-type evaporators called vacuum pans which must be supersaturated in order to entrain the sugar on the pan. Finishing provides drying or granulation which removes moisture and separates the crystals that are later cooled and fine-screened.

The molasses produced as a byproduct of cane sugar refining is used as a sweetener, as an ingredient for animal feed, for the making of alcohol, for organic chemicals, and other uses.

It is estimated that the capacity of the cane sugar industry in 1971 was 30,539 metric tons per day of melted sugar.

Waste Sources and Pollutants. Major process waste from cane sugar refining include char wash, wastewater from decolorization, and activated carbon process water from non-char refineries. Most of the waste streams produced in other processes are recovered as low purity sweet water. Wastewater from barometric condenser cooling is usually recirculated and represents a minor waste stream.

Sources of wastewater pollutants are associated with the water used as an integral part of the process (primarily the decolorization techniques of either bone char washing or activated carbon washing), the result of entrainment of sucrose into barometric condenser cooling water, and the water used to slurry the filter cake.

Parameters under effluent guidelines for meeting BPT, BAT, and NSPS include $BOD\underline{5}$, suspended solids, and pH. Additional parameters of significance include COD, temperature, sucrose, alkalinity, total coliforms, fecal coliforms, total dissolved solids, and nutrients.

Currently, 50 percent of crystalline sugar refineries and 60 percent of liquid cane sugar refineries discharge into municipal systems. The average wastewater discharged is 38.4 m^3/kkg from crystalline sugar refineries, and 18.8 m^3/kkg from liquid cane sugar refineries.

Control Technology and Costs. Current technology for control and treatment of cane sugar refinery wastewaters consists primarily of process control (recycling and reuse of water, prevention of sucrose entrainment in barometric condenser cooling water, recovery of sweet waters), impoundage (land retention), and disposal of process water to municipal sewer systems.

Best Practicable Technology consists of a combination of in-plant changes and end-of-pipe treatment. In-plant changes include: (1) collection and recovery of all floor drainage, (2) use of improved baffling systems, demisters, and/or other control devices to minimize sucrose entrainment in barometric condenser cooling water, and (3) dry handling of filter cakes after desweetening with disposal to sanitary landfills, or complete containment of filter cake slurries. End-of-pipe treatment consists of biological treatment of all wastewater discharges other than uncontaminated (non-contact) cooling water and barometric condenser cooling water.

Best Available Technology is essentially the same but, in addition to BPT, the following are applicable: (1) recycle of barametric condenser cooling water by utilizing either a cooling tower or pond, (2) biological treatment of the assumed 2 percent blowdown from the cooling system, and (3) sand filtration of effluent from the biological treatment system. Essentially, the same control technology is applicable to both crystalline and liquid cane sugar refineries.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

	Phase I & Phase II	Phase I	Phase II
Incremental BPT Investment	$21.6	7.7	13.9
Incremental BPT O&M	$ 6.4	2.2	4.1

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Principal reasons for differences between these cost estimates and the newer data are industry definition expansion (G&P includes the Phase II segment of the industry), and differences in attribution of O&M to federal laws. Note that Phase I estimates from both studies are, nonetheless, within an acceptable range of computational variance.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-3-1.
Cane Sugar Refining
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (kkg/Day)	30,679	38,801	40,731
Annual Growth Rate Over the Period 1976-1985 = 3.49%			
EFFLUENTS (1,000 MT/Yr)	**1977**	**1983**	**1985**
1971 Controls:			
Crystalline:			
TSS	28.20	35.14	36.82
BOD$_5$	6.02	7.50	7.86
Liquid:			
TSS	6.13	7.64	8.00
BOD$_5$	1.74	2.17	2.28
Legislated Controls:			
Crystalline:			
TSS	7.94	0.86	0.69
BOD$_5$	3.55	1.12	0.39
Liquid:			
TSS	1.73	0.14	0.08
BOD$_5$	0.63	0.14	0.09

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	7.13	(BPT)	9.70	(BAT)	13.25
Pretreatment	0.00		0.00		0.00

Table 4-3-1. (Continued)
Cane Sugar Refining
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)		COST IN YEAR		
New Plants	0.20	4.93	6.09	
Municipal Investment Recovery	0.97	7.68	11.29	
Totals	8.31	22.31	30.63	
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	0.96	2.89	3.04	18.91[2]
O&M[3]				
On-site Treatment	2.88	4.32	6.47	40.00
Pretreatment	0.0	0.0	0.0	0.0
Totals	2.88	4.32	6.47	40.00
Municipal Charges				
Investment Recovery	0.44	1.43	1.45	11.29
User Charges[4]	0.74	1.21	1.23	15.13
Totals	1.18	2.63	2.68	26.42
Grand Totals	5.02	9.84	12.19	85.34

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Cane Sugar industry includes crystalline cane sugar refining and liquid cane sugar refining.

DAIRY PROCESSING INDUSTRY

Production Characteristics and Capacities. In 1970, there were 5,241 dairy plants reported in the United States. The size of each plant is determined by the number of employees required, where a small operation has 1-19 employees, a medium one has 20-99 employees, and the largest over 100 employees.

The dairy processing industry comprises 12 product-related operations: (1) receiving stations, (2) fluid products, (3) cultured products, (4) cottage cheese, (5) butter, (6) natural cheese, (7) ice cream, (8) ice cream mix, (9) condensed milk, (10) dry milk, (11) condensed whey, and (12) dry whey.

A great variety of operations are employed in the dairy products industry, but for simplification, they are considered to be a chain of operations involving: (1) receiving and storage, (2) clarification, (3) separation, (4) pasteurization, and (5) packaging.

Receiving and storage of raw materials is conducted by using bulk carriers, pumps, and refrigerated tanks. Clarification is the removal of suspended matter by centrifugation. Separation is the removal of cream by centrifugation. Pasteurization is accomplished by passing the material through a unit where it is first rapidly heated and cooled by contact with heated and cooled plates or tubes. Packaging involves the final handling of the finished product prior to storage.

In 1970, a total of 51 billion kilograms of milk was processed. Of this total, 36.5 billion kilograms of final products were produced.

Waste Sources and Pollutants. Materials are lost through direct processing of raw materials into finished products and from ancillary operations. The former group consists of milk, milk products, and non-dairy ingredients (sugar, fruits, nuts, etc.), while the latter consists of cleaners and sanitizers used in cleaning equipment and lubricants used in certain handling equipment. All of these contribute to the release of organic materials, which exert a high BOD, and suspended solids to the process water. Phosphorous, nitrogen, chlorides, heat, and dairy fat can also be found.

The major waste sources in the dairy products processing industry come from the following: (1) washing and cleaning out of product remaining in tanks and piping performed routinely after every processing cycle, (2) spillage produced by leaks, overflow, freezing-on, boiling-over and careless handling, (3) processing losses, (4) wastage of spoiled products, returned products, or by-products such as whey, and (5) detergents used in the washing and sanitizing solutions.

The primary waste materials that are discharged to the waste streams in practically all dairy plants include: (1) milk and milk products received as raw materials, (2) milk products handled in the process and end-products manufacture, (3) lubricants (primarily soap and silicone based) used in certain handling equipment, and (4) sanitary and domestic sewage from toilets, washrooms, and kitchens. Other products, such as non-dairy ingredients (sugar, fruits, flavors, and fruit juices) and milk by-products (whey, buttermilk) are potential waste contributors.

The basic parameters used in establishing effluent guidelines are: BOD_5, suspended solids, and pH. It is recommended that the pH of any final discharge be within a range of 6.0-9.0.

Control Technology and Costs. Dairy wastes are usually subjectable to biological breakdown. The standard practice to reduce oxygen-demanding materials in the wastewater has been to use secondary or biological treatment consisting of: activated sludge, trickling filters, aerated lagoons, stabilization ponds or land disposal. Tertiary treatment (sand filtration, carbon adsorption) is practically nil at the present time.

BPT and BAT consists essentially of the same practices. In-plant control includes improvement of plant maintenance, waste monitoring equipment and quality control improvements. End-of-pipe control includes biological treatment (activated sludge, trickling filters or aerated lagoons) followed by sand filtration. BAT, in addition to BPT, includes multi-media filtration.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	$54.3
Incremental BPT O&M	$10.6

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. The principal reasons for differences between these cost estimates and the new data are substantially different estimates "capital-in-place" for particular segments of the industry and projected growth patterns within the industry.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-4-1.
Dairy
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (1,000 kg ME/Day)	865,439	948,840	981,318
Annual Growth Rate Over the Period 1976-1985 = 1.45%			
EFFLUENTS (1,000 MT/Yr)	**1977**	**1983**	**1985**
1971 Controls:			
Fluid Milk, Cottage Cheese:			
TSS	0.93	1.02	1.05
BOD_5	3.10	3.39	3.49
Butter:			
TSS	2.64	3.35	3.54
BOD_5	6.48	8.22	8.68
Natural, Processed Cheese:			
TSS	0.40	0.49	0.52
BOD_5	7.50	9.15	9.61
Ice Cream & Frozen Desserts:			
TSS	0.38	0.43	0.44
BOD_5	0.75	0.85	0.88
Legislated Controls:			
Fluid Milk, Cottage Cheese:			
TSS	0.63	0.27	0.17
BOD_5	1.94	1.06	0.87
Butter:			
TSS	0.68	0.02	0.02
BOD_5	2.04	0.19	0.04
Natural, Processed Cheese:			
TSS	0.15	0.02	0
BOD_5	2.40	0.33	0.17
Ice Cream & Frozen Desserts:			
TSS	0.38	0.18	0.11
BOD_5	0.76	0.52	0.43

Table 4-4-1. (Continued)
Dairy
Industry Data Summary

CONTROL COSTS (Million 1975 $)			AGGREGATED OVER		
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	384.65	(BPT)	119.45	(BAT)	322.23
Pretreatment	0.0		0.0		0.0
New Plants	2.32		146.45		193.53
Municipal Investment Recovery	95.63		769.32		1,129.67
Totals	482.60		1,035.22		1,645.42

CONTROL COSTS (Million 1975 $) - (Continued)		COST IN YEAR		
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	50.88	85.85	92.04	675.67[2]
O&M[3]				
On-site Treatment	46.65	71.26	114.31	662.72
Pretreatment	0.0	0.0	0.0	0.0
Totals	46.65	71.26	114.31	662.72
Municipal Charges				
Investment Recovery	43.38	142.49	144.82	1,129.67
User Charges[4]	76.02	112.50	113.11	1,472.93
Totals	119.40	254.99	257.93	2,602.60
Grand Totals On-site Treatment	216.93	412.11	464.28	3,940.99

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[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

Table 4-4-1. (Continued)
Dairy
Industry Data Summary

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Dairy industry products and operations include fluid milk, cottage cheese, butter, natural cheese, ice cream and frozen desserts, and condensed and evaporated milk.

FRUITS AND VEGETABLES INDUSTRY

Production Characteristics and Capacities. The fruits and vegetables processing industry includes processors of canned fruits and vegetables, preserves, jams, jellies, dried and dehydrated fruits and vegetables, frozen fruits and vegetables, fruit and vegetable juices, and specialty items. The effluent limitations guidelines issued by the EPA are limited to processors of apple products (except caustic peeled and dehydrated products), citrus products (except pectin and pharmaceutical products), and frozen and dehydrated potato products. The principal items in each group are as follows:

- Apples: slices, sauce, and juice (cider)
- Citrus: juice, segments, oil, dried peel, and molasses
- Potatoes: chips, frozen products, dehydrated products, canned hash, stew, and soup products.

The manufacturing processes employed, which depends upon the particular product, include: harvesting, receiving, storage, washing and sorting, peeling and coring, sorting, slicing, segmenting or dicing, pressing or extraction (for juice products), cooking, finishing, blanching (for potatoes), juice concentration, dehydration, canning, freezing, can rinsing and cooling, and cleanup. Many processes previously performed by hand, such as peeling and coring, have been automated. Peeling, for example, may be performed mechanically or caustically, a process in which the fruit or vegetable is dipped in a hot lye solution to loosen and soften the peel, which is then removed by brushes and water spray.

The canning and freezing industry is characterized by a large number of small, single-plant firms. These firms share a very small segment of the total market and have very little influence on industry prices and total supply. Over the past 20 years, there has been a steady trend in the industry to fewer large plants from many smaller operations. The four largest firms in the canning, freezing, and dehydrating industries account for approximately 20, 25, and 35 percent, respectively, of the total value of industry shipments. Although a large proportion of the plants are relatively old, the industry has generally maintained modern technology through renovation and equipment modernization.

It is likely that the trend toward fewer plants is also expected to continue. New large plants will probably continue to replace the production capacity of the small, older plants that will close.

Waste Sources and Pollutants. Water is used extensively in all phases of the food processing industry; it is used as:

- A cleaning agent to remove dirt and foreign material
- A heat transfer medium for heating and cooling
- A solvent for removal of undesirable ingredients from the product
- A carrier for incorporation of additives into the product
- A method of transporting and handling the product.

Although the steps used in processing the various commodities display a general similarity, there are variations in the equipment used and in the amount and character of the wastewaters produced. For example, caustic peeling produces a much higher pollution load than does mechanical peeling. Similarly, water transport adds a great deal to a plant's wastewater flow compared to dry transportation methods.

The pollutant parameters that have been designated by EPA as of major significance for apple, citrus, and potato processors are BOD, suspended solids, and pH. Minor pollutant parameters include COD, total dissolved solids, ammonia and other nitrogen forms, phosphorus, fecal coliforms, and temperature.

Control Technology and Costs. Control technologies applicable to wastewaters from the fruit and vegetable processing industry consist of both in-plant (or in-process) technologies and as conventional end-of-pipe waste treatment technologies. In-plant control methods include field washing of crops, substitution of dry transport methods for flumes, replacing conventional hot water and steam blanching methods by fluidized bed, microwave, hot gas, or individual quick blanching methods, using high pressure nozzles and automatic shutoff valves on hoses, reuse of process waters using counter-current flow systems, recirculation of cooling waters, etc., and minimum use of water and detergents in plant cleanup.

End-of-pipe treatment technologies used in the fruits and vegetables processing industry generally include preliminary screening, equalization, catch basins for grease removal, sedimentation and clarification, followed by a biological treatment system such as activated sludge, trickling filter, anaerobic lagoons or aerated lagoons. Where necessary, neutralization and chlorination are also included. Other technologies that are or may be used by the industry include solids removal by air flotation or centrifugal separation, chemical coagulation and precipitation, biological treatment through the use of a rotating biological contactor, sand or diatomaceous earth filtration, and other advanced treatment technologies. The liquid portion of cannery wastes can be "completely" treated and discharged through percolation and evaporation lagoons or by spray irrigation.

Because the wastes from fruit and vegetable processing plants are primarily biological, they are compatible with municipal sewage treatment systems, therefore, discharge into municipal systems is also a practicable alternative for fruit and vegetable processors.

BPT guidelines are based upon the average performances of exemplary biological treatment systems. Thus, the technology called for includes preliminary screening, primary settling (potatoes only), and biological secondary treatment. Cooling towers for the recirculation of weak cooling water is considered BPT for the citrus industry. In-plant control methods should include good housekeeping and water use practices. No special in-plant modifications are required. Land treatment methods such as spray irrigation are of course, not excluded from use.

BAT and NSPS guidelines assume the use of BPT, plus additional secondary treatment, such as more aerated lagoons and/or shallow lagoons and/or a sand filter following secondary treatment; disinfection (usually chlorination) is also included. Management controls over housekeeping and water use practices are assumed to be stricter than BPT. Although no additional in-plant controls are required, several modifications may be economically more attractive than additional treatment facilities. These include: recycling raw material wash water, utilization of low water useage peeling equipment, recirculation of cooling water, and utilization of dry cleanup methods. Where suitable land is available, land treatment is not only recommended from the discharge viewpoint, but will usually be more economical than other treatment methods.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	$35.2
Incremental BPT O&M	$ 4.4

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Principal reasons for differences between these cost estimates and the newer data are changes in abatement strategy: G&P assume some plants use land disposal, some use activated sludge and some use "no cost" methods, whereas SEAS assumes all facilities currently without controls will install activated sludge systems which have costs two to six times higher.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-5-1.
Fruits and Vegetables
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (Million Liters/Day)	2,420	3,157	3,395

Annual Growth Rate Over the Period 1976-1985 = 4.29%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	62.55	81.00	86.85
BOD$_5$	46.22	59.85	64.18
Legislated Controls:			
TSS	27.24	14.77	11.74
BOD$_5$	21.70	23.03	23.58

CONTROL COSTS (Million 1975 $)			AGGREGATED OVER		
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	60.82	(BPT)	99.69	(BAT)	130.14
Pretreatment	0.00		0.00		0.00
New Plants	16.25		102.14		139.64
Municipal Investment Recovery	28.20		226.62		333.08
Totals	105.27		428.45		602.86

Table 4-5-1. (Continued)
Fruits and Vegetables
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	10.13	36.67	40.68	238.70[2]
O&M[3]				
On-site Treatment	28.54	45.59	62.72	407.26
Pretreatment	0.0	0.0	0.0	0.0
Totals	28.54	45.59	62.72	407.26
Municipal Charges				
Investment Recovery	12.64	42.14	42.90	333.08
User Charges[4]	21.65	36.17	37.26	451.22
Totals	34.29	78.31	80.15	784.29
Grand Totals	72.97	160.56	183.55	1,430.26

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Fruits and Vegetables industry includes all aspects of canned and preserved food processes, and frozen packaged foods.

GRAIN MILLING INDUSTRY

Production Characteristics and Capacities. For purposes of establishing water effluent guidelines, the grain milling industry is divided into four major subcategories: wet corn milling, dry corn milling, bulgur wheat flour milling, and parboiled rice milling. Two other subcategories, normal wheat flour milling and normal rice milling, have been excluded because they do not use process water.

Wet corn milling comprises three basic process operations: milling, starch production, and syrup manufacturing. The finished products of starch and corn sweeteners are used for paper products, food products, textile manufacturing, building materials, laundries, home uses, and miscellaneous operations.

Dry corn milling process separates the various fractions of corn, namely the endosperm, brain, and germ. These fractions are later ground and sifted after separation. The final products include: corn meal, grits, flour, oil, and animal feed.

Bulgur wheat flour milling produces parboiled, dried, and partially debranned wheat for use in either cracked or whole grain form. Bulgur is produced primarily for the Federal Government as part of a national effort to utilize surplus wheat for domestic use and for distribution to underdeveloped countries.

Parboiled rice milling utilizes rice that is carefully cleaned, parboiled by soaking in water, and then cooked to gelatinize the starch. After cooking, the water is drained and the parboiled rice is dried before milling. The bran and germ are later separated from the milled rice. The final product has superior cooking qualities because vitamins from the bran are forced into the endosperm.

The use of dry corn milling products in direct food has declined significantly over the past 20 years but this decline has been offset by the growing use of the products as ingredients in processed foods. Consumption of bulgur wheat flour milling products has been increasing in developing nations due to the high nutritional values of bulgur wheat. Rice milling including parboiled products are 60 percent exported and 40 percent used for domestic trade.

Waste Sources and Pollutants. Principal wastewater sources in wet corn milling are modified starch washing, condensate from steepwater evaporation, mud separation, syrup evaporation, animal feeds, and corn steeping. Dry corn milling process wastes originate from infrequent washing of corn. Bulgur wheat flour milling process wastewater stems from steaming and cooking of bulgur, although these quantities are relatively small. Parboiled rice milling process wastewater stems from steeping or cooking operations, and at least one plant uses wet scrubbers for dust control, which generates an additional source of wastewater.

The basic parameters used to define wastewater characteristics are BOD_5, suspended solids and pH. About one-fourth of the wet corn milling plants discharge directly into surface water. The majority of the plants in the other subcategories discharge into municipal systems.

Control Technology and Costs. Except for wet corn milling, little attention has been focused on either in-plant control or treatment of the wastewaters. In many instances, the treatment technologies developed for wet corn milling can be transferred to the other industry subcategories. Current in-plant control consists of water recycling cooling systems (barometric condensers), and some plants use biological treatment (activated sludge).

Best practicable technology for the four subcategories consists of the following:

Phase I

- Wet corn milling. Equalization and activated sludge
- Dry corn milling. Primary sedimentation and activated sludge
- Bulgur wheat flour milling. Activated sludge, and
- Parboiled rice milling. Activated sludge.

Best available technology for the four subcategories is deep bed filtration in addtion to BPT. New source performance technology is the same as BAT.

Since the wet corn milling industry contributes the largest amount of wastewater discharges, control costs for this industry are of primary concern.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

	Phase I & Phase II	Phase I	Phase II
Incremental BPT Investment	0.	0.	0.
Incremental BPT O&M	0.	0.	0.

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Phase II costs are assumed to be zero for in-house treatment by both studies. All costs associated with Phase II production are municipal treatment changes. The G&P study states that only negligible costs will be incurred by Phase I production, since only one of the plants not using municipal systems to discharge wastes has not fully installed the necessary equipment. SEAS lists five plants requiring equipment, with 44 percent already installed prior to standard implementation.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972," National Bureau of Economic Research, December 1975. (Revised January 1976).

Table 4-6-1.
Grain Milling
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity:			
Phase I (Dry 1,000 Liters/Day)	45,623.	55,535.	58,278.5
Phase II (kkg/Day)	8,584,400.	11,641,700.	12,598,000.

Annual Growth Rate Over the Period 1976-1985:
Phase I = 13.02%
Phase II = 4.83%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	10.70	13.87	14.70
BOD$_5$	15.14	19.65	20.83
Legislated Controls:			
TSS	5.76	2.69	1.49
BOD$_5$	6.57	3.62	2.79

CONTROL COSTS (Million 1975 $)			AGGREGATED OVER		
Phase I					
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	12.27	(BPT)	0.0	(BAT)	5.46
Pretreatment	0.0		0.0		0.0
New Plants	0.54		6.24		7.30
Municipal Investment Recovery	14.53		124.94		183.30
Totals	27.34		131.18		196.06

Table 4-6-1. (Continued)
Grain Milling
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Phase I (Continued)				
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	1.68	2.51	2.64	21.44[2]
O&M[3]				
On-site Treatment	2.11	2.85	3.06	25.23
Pretreatment	0.0	0.0	0.0	0.0
Totals	2.11	2.85	3.06	25.23
Municipal Charges				
Investment Recovery	6.74	23.31	23.75	183.30
User Charges[4]	12.23	21.02	21.71	256.87
Totals	18.97	44.33	45.47	440.17
Grand Totals	22.76	49.68	51.16	486.83

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Grain Milling (Phase I), industry includes wet-corn milling processes.

Table 4-6-1. (Continued)
Grain Milling
Industry Data Summary

Phase II

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	0.0	(BPT)	0.0	(BAT)	0.0
Pretreatment	0.0		0.0		0.0
New Plants	0.0		0.0		0.0
Municipal Investment Recovery	1.02		12.68		18.42
Totals	1.02		12.68		18.42

	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	0.0	0.0	0.0	0.0[2]
O&M[3]				
On-site Treatment	0.0	0.0	0.0	0.0
Pretreatment	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Municipal Charges				
Investment Recovery	0.57	2.39	2.45	18.42
User Charges[4]	1.30	2.48	2.67	29.03
Totals	1.86	4.88	5.12	47.45
Grand Totals	1.86	4.88	5.12	47.45

Table 4-6-1. (Continued)
Grain Milling
Industry Data Summary

Phase II (Continued)

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Grain Milling (Phase II) industry includes ready-to-eat cereals, wheat starch, and gluten production processes.

MEAT PROCESSING INDUSTRY

Production Characteristics and Capacities. According to the Department of Agriculture, there were 5,991 meat slaughtering plants in the United States on March 1, 1973. Commercial slaughter of beef, hogs, calves, sheep, and lambs totaled 26.9 million metric tons in 1972 according to the USDA. Of these plants, 84 were large plants [over 90,800 metric tons annual live weight killed (LWK)], 309 medium plants (11,340-90,247 metric tons annual LWK), and the rest were small. Of the small plants, North Star Research Institute estimated 5,200 to be "locker" plants (very small meat packing plants that slaughter animals and may produce processed meat products which are usually stored in frozen form). The other 400 plants are assumed to be plants between 453.5-11,340 metric tons annual LWK.

A total of 90 percent of the industry's production is accounted for by 15 percent of the plants. Although the total number of plants in North Star's slaughterhouse and packinghouse categories is only 793 (15 percent of 5,993 is 899), they assumed that these plants produce 90 percent of the output, and locker plants account for the remaining 10 percent.

The meat processing industry comprises four subcategories: simple slaughterhouse, complex slaughterhouse, low-processing packinghouse, and high-processing packinghouse. The plants in this industry range from those that carry out only one operation, such as slaughtering, to plants that also carry out commercial meat processing.

Simple slaughterhouses have very limited byproduct processing and usually no more than two other operations such as: rendering, paunch and viscera handling, blood processing, or hide processing. Complex slaughterhouses carry out extensive byproduct processing with at least three of the aforementioned operations. Low process packinghouses process only animals killed at the plant; normally they process less than the total kill. High process packinghouses process both animals slaughtered at the site and additional carcasses from outside sources.

Income from meat slaughtering and meat processing plants in 1972 was $23.8 million. Factors serving to restrain potential growth of the American meat packing industry include higher meat prices, removal of import quotas, and the availability of synthetic (soybean protein) substitutes. The trend is for any new plants to be larger and more specialized (such as large beef or pork slaughterhouses) and to be located closer to the animal supply (movement from urban to rural areas).

Waste Sources and Pollutants. Wastewaters from slaughterhouses and packinghouses contain organic matter including grease, suspended solids, and inorganic materials such as phosphates, nitrates, and salt. These materials enter the waste stream as blood, meat and fatty tissue, meat extracts, paunch contents, bedding, manure, hair, dirt, curing and pickling solutions, preservatives, and caustic or alkaline detergents.

Water is a raw material used in the meat processing industry to cleanse products and to remove unwanted material. The primary operations where waste water originates are: animal holding pens (waste from water troughs, washdown, and liquid wastes), slaughtering (killing, blood processing, viscera handling and offal washing, and hide processing), and clean-up.

The basic parameters used to define waste characteristics are BOD_5, suspended solids, grease, and ammonia (NSPS and BAT). The total number of municipal dischargers is 70 percent of the number of plants. The average wastewater flows for simple slaughterhouse, complex slaughterhouse, low-process packinghouse, high-process packinghouse are 1.17, 4.40, 3.22, and 4.55 million liters per day, respectively.

Control Technology and Costs. Current end-of-pipe treatment for direct dischargers assumes that all plants have in-plant controls for primary treatment, and a second system employing anaerobic and aerobic lagoons. Dissolved air flotation is used for primary treatment, either alone or with screens; however, 30 percent of the plants use a catch basin. Since a small percentage of the industry has more advanced secondary treatment systems (such as activated sludge, trickling filters or spray irrigation) and a small percentage of meat packers have no waste treatment beyond primary treatment, it can be assumed that the typical plant today is characterized by primary treatment plus anaerobic and aerobic lagoons.

Best Practicable Technology consists of end-of-pipe treatment represented by anaerobic plus aerated lagoon and aerated lagoon with efficient solid liquid separation. Disinfection by chlorination is also required. Land disposal, when available, may be an economical option. End-of-pipe treatment is assumed to be preceded by in-plant controls: reduction of water use through shut-off valves, extensive dry cleaning, gravity catch basins, blood recovery and dry dumping of paunch waste. NSPS are the same for 1977 with an additional requirement for control of ammonia.

In addition to BPT, Best Available Technology suggests chemical additions prior to dissolved air flotation, nitrification denitrification (or ammonia stripping), and sand filtration following Secondary Treatment.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

	Meats Phase I	Meats Phase II	Rendering	Poultry
Incremental BPT Investment	90.5	3.4	1.8	21.1
Incremental BPT O&M	7.2	0.6	0.4	3.4

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. The SEAS cost estimates for Meat Processing include Phase I only. For slaughterhouses and packing houses, both studies assumed the same number of plants and discharge levels to municipalities in the base data year. A major difference is that G&P includes estimates for Locker Plants in the Phase I costs, which SEAS does not. Locker Plants amount to almost half of the G&P Phase I estimates. The remaining differences are largely due to variances in capital in place assumptions between the two stuides.

Poultry Processing estimates are within an acceptable range of computational variance.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-7-1.
Meat Processing and Poultry
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity:			
Meat (kkgs/Day)	305,373.	372,322.	395,520.
Poultry (kkg/Day)	50,340.	61,365.	65,188.

Annual Growth Rate Over the Period 1976-1985 = 3.21%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	106.51	129.74	137.60
BOD$_5$	182.08	221.79	235.24
COD (Poultry only)	68.31	83.20	88.25
Oils and Greases	304.31	370.67	393.14
Legislated Controls:			
TSS	40.61	11.57	8.70
BOD$_5$	56.70	8.94	6.86
COD (Poultry only)	21.52	4.78	4.23
Oils and Greases	82.35	3.56	2.35

CONTROL COSTS (Million 1975 $) Meat Processing		AGGREGATED OVER	
Investment	1974-77	1978-83	1976-85
Existing Plants			
On-site Treatment	17.54 (BPT)	302.07 (BAT)	311.61
Pretreatment	0.00	0.00	0.00
New Plants	29.36	58.29	109.03
Municipal Investment Recovery	58.19	498.97	731.46
Totals	105.10	859.33	1,152.10

Table 4-7-1. (Continued)
Meat Processing and Poultry Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued) Meat Processing (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	6.17	53.54	56.87	274.64[2]
O&M[3]				
On-site Treatment	16.27	49.09	220.67	643.01
Pretreatment	0.0	0.0	0.0	0.0
Totals	16.27	49.09	220.67	643.01
Municipal Charges				
Investment Recovery	26.99	92.81	94.47	731.46
User Charges[4]	49.05	78.74	80.70	996.70
Totals	76.03	171.55	175.17	1,728.16
Grand Totals	98.47	274.19	452.70	2,645.81

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Meat Processing industry includes slaughterhouse and packinghouse processing operations.

Table 4-7-1. (Continued)
Meat Processing and Poultry
Industry Data Summary

CONTROL COSTS (Million 1975 $) Poultry	AGGREGATED OVER			
Investment	1974-77		1978-83	1976-85
Existing Plants				
On-site Treatment	17.80	(BPT)	38.26 (BAT)	46.84
Pretreatment	0.00		0.00	0.00
New Plants	8.52		12.71	24.70
Municipal Investment Recovery	25.42		223.63	327.58
Totals	51.74		274.60	399.12

	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	3.46	10.16	10.79	65.60[2]
O&M[3]				
On-site Treatment	3.74	5.87	19.75	75.53
Pretreatment	0.0	0.0	0.0	0.0
Totals	3.74	5.87	19.75	75.53
Municipal Charges				
Investment Recovery	11.90	41.66	42.43	327.58
User Charges[4]	22.07	36.42	37.92	454.51
Totals	33.96	78.08	80.35	782.09
Grand Totals	41.17	94.11	110.89	923.22

Table 4-7-1. (Continued)
Meat Processing and Poultry
Industry Data Summary

Poultry (Continued)

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Poultry industry includes prepareation of most domestic fowl products, such as frozen ducks, turkeys, chickens, and game birds.

SEAFOOD PROCESSING INDUSTRY

Production Characteristics and Capacities. There are approximately 1,800 seafood processors located in the United States, including tuna processing plants located in Puerto Rico and American Samoa. The crab, shrimp, and catfish processers have a large number of small producers. Some of these are associated with large national seafoods processors, but there is no significant degree of concentration in these industries. In the crab processing industry, there seems to be an increasing number of multiplant firms and a growing importance of large plants. The catfish processing industry is very small and fragmented. This study's count of 30 plants does not include a number of very small "backyard" operations which are thought to be scattered throughout the South. In general, these segments of the seafood processing industry can be characterized as possessing many small, underutilized, old plants that in some cases compete with efficient, low-cost foreign producers.

On the other hand, the tuna industry is dominated by five firms that operate 14 large-scale plants which account for over 90 percent of the industry production; these firms are: Bumble Bee, Del Monte, Starkist, Van Camp, and Westgate-California.

In general, the volume of production is dependent upon the amount of seafood harvested, both domestic and imported. Recent analyses by the U.S. National Marine Fisheries Service indicate that there is little potential available for continuing to increase either harvests or imports of crab, shrimp, or tuna. Significant increases might come if the limit of the U.S. territorial waters is extended to 200 miles, or if significant technological breakthroughs are achieved in deep ocean fishing; but these conditions are not anticipated.

Because catfish processors are currently plagued with very low utilization of capacity, the same expectation of "no growth" holds for this segment of the seafood processing industry.

The effluent limitations guidelines issued for the seafood processing industry by the EPA cover the processing of crab, shrimp, tuna, and farmed catfish. All methods of preservation, fresh-pack, freezing, canning or curing, are included.

Processing seafood involves variations of a common sequence of operations: harvest, storage, receiving, preprocessing (washing, thawing, etc.), evisceration, precooking, picking or cleaning, preservation, and packaging. Many of the operations, such as picking, shelling, and cleaning, have been mechanized, but much of the industry still depends on conventional hand operations.

For the purpose of establishing effluent limitations guidelines, the seafood processing industry has been divided into 14 subcategories. These guidelines are based upon the type of product, the degree of mechanization, and the location or remoteness of the processing plant. Remote Alaskan plants have been placed in a separate subcategory because their isolated locations render most wastewater treatment alternatives infeasible because of the high cost of overcoming engineering obstacles and the undependable access to transportation during extended severe sea or weather conditions.

Waste Sources and Pollutants. Pollution sources in the seafood processing industry include both the fishing boats (mostly their discharged bilge water) and the processing plants themselves. Water uses in the processing plants include: washing the seafood, plants, and equipment; flumes for in-plant transport of product and wastes; live holding tanks; cooling and ice making; cooking; freezing; and brining.

The solids and effluents from all fish and shellfish operations consist of:

- Solid portions consisting of flesh, shell, bone, cartilage and viscera.
- Hot and cold water (fresh or seawater) solutions containing dissolved materials (proteins and breakdown products),
- Suspended solids consisting of bone, shell or flesh,
- Foreign material carried into the plant with the raw material.

The following pollutant parameters are controlled by the effluent limitations guidelines for the seafood processing industry: 5-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), and oil and grease. Pollutants of peripheral or occasional importance that are not specifically controlled by the guidelines include high temperatures, phosphorus, coliforms, chloride, chemical oxygen demand, settleable solids, and nitrogen.

Control Technology and Costs. Control technologies applicable to the seafood processing industry include both in-plant changes and end-of-pipe treatment. Basic in-plant changes include:

- Minimizing the use of water by substituting dry handling for flumes, using spring-loaded hose nozzles, etc.

- Recovery of dissolved proteins by precipitation from effluent streams, enzymatic hydrolysis, brine-acid extraction, or through the conventional reduction process for converting whole fish or fish waste to fish meal.

- Recovery of solid portions for use as edible product or as byproducts by mechanical deboning and extruding, and by shellfish waste utilization.

Very few end-of-pipe waste treatment systems are currently installed in the seafood processing industry. However, the essentially bio-degradable nature of the wastes allows for the easy application of conventional treatment methods. These include screening and sedimentation to remove suspended solids; air flotation and skimming to remove heavy concentrations of solids, greases, oils, and dissolved organics; biological treatment systems, such as activated sludge, rotating biological contactors, trickling filters, ponds, and lagoons to remove organic wastes; and land disposal methods where land is available.

In general, BPT guidelines call for in-plant "good housekeeping" practices, but do not assume significant equipment changes. End-of-pipe technologies associated with BPT are represented by simple screening and grease trap methods, with dissolved air flotation for tuna plants and grinders or comminutors, followed by discharge to deep water for remote Alaskan processors where adequate flushing is available. BAT and NSPS guidelines place much more emphasis on in-plant changes, including in-process modifications which promote efficient water and wastewater management to reduce water consumption, recycling some water streams, and solids or byproduct recovery where practicable. End-of-pipe technologies associated with BAT and NSPS guidelines include more extensive use of dissolved air flotation, plus the addition of aerated lagoons and activated sludge treatment for tuna processors in 1983.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	$39.5
Incremental BPT O&M	$ 3.9

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Principal reasons for differences between these cost estimates and the new data are different estimates of "capital-in-place" and plant inventory estimates (SEAS calculates costs for 875 plants, but G&P uses a baseline of 330 plants).

[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-8-1.
Seafood Processing
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (kkg/Day)			
Canned & Cured	58,449.	76,238.	81,977.
Fresh & Frozen	382,587.	499,072.	536,649.

Annual Growth Rate Over the Period 1976-1985 = 4.29%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	23.35	30.24	32.42
BOD5	30.72	39.78	42.65
Bases	.08	.10	.11
Oils and Greases	11.44	14.82	15.89
Legislated Controls:			
TSS	16.79	10.34	8.02
BOD5	26.00	17.62	13.90
Bases	.04	.04	.04
Oils and Greases	7.23	4.16	3.26

CONTROL COSTS (Million 1975 $)		AGGREGATED OVER			
Phase I					
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	266.21	(BPT)	511.24	(BAT)	641.20
Pretreatment	0.00		0.00		0.00
New Plants	62.96		370.98		501.92
Municipal Investment Recovery	0.0		0.0		0.0
Totals	329.17		882.22		1,143.13

Table 4-8-1. (Continued)
Seafood Processing
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	43.28	129.27	133.03	841.48[2]
O&M[3]				
On-site Treatment	88.78	145.53	280.83	1,444.28
Pretreatment	0.0	0.0	0.0	0.0
Totals	88.78	145.53	280.83	1,444.28
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	132.06	274.80	413.85	2,285.76

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Seafood (Phase I) industry includes fresh and frozen packaged fish products.

Table 4-8-1. (Continued)
Seafood Processing
Industry Data Summary

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER		
Phase II			
Investment	1974-77	1978-83	1976-85
Existing Plants			
On-site Treatment	91.31 (BPT)	120.69 (BAT)	165.21
Pretreatment	0.00	0.00	0.00
New Plants	20.27	119.01	161.12
Municipal Investment Recovery	0.0	0.0	0.0
Totals	111.58	239.70	326.33

	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital	14.67	46.18	50.61	317.59[2]
O&M[3]				
On-site Treatment	28.13	46.58	54.16	389.33
Pretreatment	0.0	0.0	0.0	0.0
Totals	28.13	46.58	54.16	389.33
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	42.80	92.77	104.77	706.92

Table 4-8-1. (Continued)
Seafood Processing
Industry Data Summary

Phase II (Continued)

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Seafood (Phase II) industry includes canned and cured seafood processing operations.

LEATHER TANNING & FINISHING INDUSTRY

Production Characteristics and Capacities. The leather tanning and finishing industry is engaged in converting animal skins into leather. Cattlehides constitute approximately 90 percent of the tanning done in the United States, followed by sheepskins, lambskins, and pigskins. Other types of skins or hides processed include goat, kid, hairsheep, horse, and a variety of skins on a very limited basis, such as deer, elk, moose, antelope, rabbit, alligator, crocodile, seal, shark, and kangaroo. Once tanned and finished, the leather from these skins is shipped by the industry to process manufacturers for the production of shoes, coats, gloves, and other leather products. Three primary processes are involved in the production of finished leather: beamhouse; tanhouse and/or retan, color and fat-liquor; and finishing.

The beamhouse process consists of receiving hides that are either cured, green-salted, or brined. Trimming, washing and soaking, fleshing (removal of fatty tissue), and unhairing are the steps that prepare hides for processing.

The tanhouse process involves placing the hides in solutions of ammonium salts and enzymes in order to de-lime, reduce swelling, peptize fibers, and remove protein degradation products. Prior to tanning, hides are pickled in a brine and acid solution, and then tanned using either chrome or vegetable tannins. The tanned hide is later split to form a grainside piece and a flesh side layer. The retan, color and fat-liquor process imparts different characteristics to the finished leather. Bleaching and coloring using acids and dyes, along with applying oils to replace the lost natural oils, allow the leather to be pliable.

The finishing process, or last step, includes drying, wet-in coating, staking or tacking, and plating. The wastes from these processes may be disposed of in either wet or dry form.

The industry may be divided into major subcategories based on the primary processes employed; these subcategories are presented in Table 4-9-1.

Table 4-9-1.
Leather Tanning Industry Subcategories

Subcategory	Beamhouse	Tanning	Leather Finishing
1	Pulp Hair	Chrome	Yes
2	Save Hair	Chrome	Yes
3	Save Hair	Vegetable	Yes
4	Hair previously removed	Previously tanned	Yes
5	Hair previously removed or retained	Chrome	Yes
6	Pulp or Save Hair	Chrome or no tanning	No

Source: EPA Development Document, March 1974.

The two processes used for unhairing are save hair and pulp hair. Save hair is a process that loosens hair by lime and sharpeners (sodium hydrosulfite, etc.); the hair is later removed from the hide by machines. Pulp hair is similar to save hair except that higher chemical concentrations are used; the proteinaceous hair is solubilized sufficiently to disperse it in the processing liquid.

There were 513 industry establishments operating in 1972; estimations are that 176 tanneries use wet process operations, and 225 to 260 plants are engaged in dry process finishing operations on leather which was tanned at some other location. Some 40 to 90 firms are estimated to be converters and miscellaneous small operators. Approximately 80 percent of the plants in the industry fall in Subcategory 1.

In 1972, a total of 36.5 million cattle (90 percent of the total hides tanned) were slaughtered in the United States; about 47 percent of these hides went to foreign tanners. The number of tanneries has steadily decreased since the turn of the century. For example, in 1967, there were 474 companies operating 519 establishments in the leather tanning and finishing industry (including dry process tanners) as compared to 521 companies and 578 establishments 10 years earlier.

After reaching a peak volume in 1967 of 32.4 million cattle hide equivalents, volume has dropped sharply each year. In 1972, volume had declined to 24.0 million cattle hide equivalents or a decrease of 25 percent from the peak year. Two major factors have contributed to this decline:

- Increased exporting of raw hides for tanning abroad.
- Increased competition from synthetic leathers, both in terms of physical product and price.

The records of the Tanner's Council of America indicate 33 plants (representing a tanning capacity of 5.3 million hides) ceased operations between 1968 and June of 1974.

Waste Sources and Pollutants. The main sources contributing to the total waste load come from the processes used in the tanning and finishing of hides. In order to define waste characteristics, the following basic parameters were used to develop guidelines for meeting BPT and BAT: BOD_5, suspended solids, total nitrogen, chromium, oil and grease (hexane solubles), sulfide, and pH.

Currently, about 60 percent of industry waste is discharged to municipal sewerage systems, while the remainder is discharged directly to surface waters. It is estimated that 60 percent of the wet-process tanners discharge to municipal sewers.

Control Technology and Costs. Waste treatment practices in the leather tanning and finishing industry vary widely. Some tanneries use no treatment or only simple screening. Others have employed activated sludge, trickling filters, spray irrigation, and lagoon systems. In-plant waste control procedures have included efforts by some tanneries to conserve water and materials. Although the potential for materials conservation has not been fully realized, recycling and recovery techniques have generally been applied only in those areas where direct cost savings are demonstrated. BPT guidelines for plants discharging to waterways call for a major removal of BOD_5 and suspended solids through the installation of preliminary treatment (chromium removal, screening, equalization and primary clarification) and secondary biological treatment (activated sludge, aerobic or anaerobic lagoons). In addition to major removals of BOD_5 and suspended solids, the BAT guideline requires reductions in sulfide and nitrogen through use of aeration and mixing with a carbon source to cause denitrification and filtration of the final effluent using deep-bed, mixed-media filters to remove suspended solids. New source performance standards are the same as BPT for existing plants.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	$79.2
Incremental BPT O&M	$ 9.1

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Principal reasons for differences between these cost estimates and the newer data are changes in plant inventory estimates, different estimates of "capital-in-place", different assumptions for industry growth, and different engineering cost estimates for O&M in BPT and pretreatment. The pretreatment investment estimates are very close for both studies; G&P lists 31.2 million dollars and SEAS forecasts 30.2.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-9-2.
Leather Tanning and Finishing
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (Hides/Day)	145,100	176,500	169,250

Annual Growth Rate Over the Period 1976-1985 = 1.88%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	43.49	47.74	45.63
BOD$_5$	23.50	25.80	24.65
Dissolved Solids	.90	.99	.94
Nutrients	10.05	11.03	10.54
Oils and Greases	8.74	9.60	9.17
Legislated Controls:			
TSS	16.51	3.02	1.21
BOD$_5$	8.18	1.71	1.10
Nutrients	10.01	2.89	.21
Oils and Greases	2.62	.50	.43
Dissolved Solids	.28	.05	.04

CONTROL COSTS (Million 1975 $)			AGGREGATED OVER		
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	82.06	(BPT)	187.54	(BAT)	229.66
Pretreatment	30.18		0.00		0.00
New Plants	8.36		50.75		50.75
Municipal Investment Recovery	3.40		26.63		39.19
Totals	124.00		264.92		319.60

Table 4-9-2. (Continued)
Leather Tanning and Finishing Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	15.86	47.18	47.18	308.56[2]
O&M[3]				
On-site Treatment	9.59	12.75	29.87	150.23
Pretreatment	5.82	7.09	6.79	66.64
Totals	15.41	19.84	36.66	216.87
Municipal Charges				
Investment Recovery	1.52	4.95	5.03	39.19
User Charges[4]	2.56	4.11	4.07	52.18
Totals	4.08	9.06	9.10	91.37
Grand Totals	35.35	76.08	92.94	616.80

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Leather industry includes tanning and finishing operations.

TEXTILES INDUSTRY

Production Characteristics and Capacities. The U.S. textile industry includes over 7,000 establishments engaged in the processing of wool, cotton, and man-made fibers into finished fabrics. Man-made fibers, including rayon, acetate, nylon, acrylic, polyester, polypropylene, and glass fibers, are the most important raw materials, accounting for over 60 percent of the raw materials consumed by the industry in 1972. Cotton accounted for about 36 percent, and wool only 2 percent of the total raw materials used.

The natural fibers are supplied to the industry in staple form, or short fibers. Man-made fibers are supplied as either staple or continuous filament. In either case, the fiber is spun into yarn, which is simply a number of filaments twisted together. The yarn is then woven or knit into a fabric, which is then dyed and treated to impart such characteristics as shrink resistance, crease resistance, etc. The finished fabric is then delivered to the manufacturers of textile products, either directly or through convertors, jobbers, and wholesalers.

In transforming fibers into the finished fabrics, two types of processes are used: wet and dry. The dry processes include spinning, weaving, knitting, bonding, and laminating; wet processes include scouring, desizing, mercerizing, bleaching, dyeing, and finishing.

For the purpose of establishing effluent limitations guidelines, the textiles industry has been divided into the following eight subcategories, based upon the raw material used and the process employed:

- Wool scouring
- Wool finishing
- Dry processing
- Woven fabric finishing
- Knit fabric finishing
- Carpet mills
- Stock and yarn dyeing and finishing
- Commission finishing.

Wool scouring is the process of washing the raw wool with detergent or solvent to remove natural grease, soluble salts, and dirt. Wool finishing operations include carbonizing (removing vegetable matter by treating the wool with sulfuric acid at high temperatures), rinsing and neutralization, fulling (chemical treatment followed by washing and mechanical working to produce controlled shrinkage), dyeing and/or whitening or bleaching, and moth proofing.

Dry processing mills include greige mills (any mill making unfinished fabric) and producers of coated fabrics, laminated fabrics, tire cord fabrics, felts, carpet tufting, and carpet backing.

Woven fabric finishing operations include desizing (acid or enzyme treatment to remove chemicals applied prior to weaving), scouring, bleaching, mercerizing (treatment with sodium hydroxide followed by neutralization and washing to increase dye affinity and add tensile strength), carbonizing, fulling, dyeing, printing, resin treatment, waterproofing, flame proofing, soil repellency, and a number of special finishes.

The main difference between woven and knit fabric finishing is that the sizing/desizing and mercerizing operations are not required for knits. Stock and yarn dyeing and finishing requires mercerizing but not sizing/desizing. Carpets are made from yarn through a dry operation called tufting, which is followed by printing or dyeing, washing, and drying. The processing operations performed in commission finishing may be any sequence of the operations discussed above.

In general, the industry is highly fragmented, with many small plants and a few very large establishments. In most industry subcategories, the small plants account for over half of the annual production.

Although the total industry production has grown at a rate of approximately 3 percent per year, this growth has been confined to the production of man-made fabrics and carpets. The cotton and wool segments of the industry have declined drastically over the years, resulting in a decline in the number of establishments, which has been caused in part by the switch to synthetic fibers and in part by an increase in imported textiles. U.S. imports of textile products and clothing have risen from $1.5 billion in 1967 to $4.0 billion in 1974; this trend is expected to continue through 1980.

Waste Sources and Pollutants. As described above, the processing and finishing of textile fabrics involve a number of wet processes that introduce a wide variety of animal and vegetable wastes, dyes, bleaches, and other chemicals into the waste streams. For example, raw wool scouring produces pollutants removed from the wool, such as oil and grease; sulfur, phenolic, and other organic materials that are separated from the sheep urine, feces, blood, etc.;

insecticides; and dirt and grit. In addition, the scouring liquor is a significant pollution source in itself, along with the chemicals used to recover oil and grease from the liquor. The scouring and rinsing of detergents, chemicals, etc., from intermediate and final products are common to most finishing operations. About 80 percent of all the water used in textile wet processing is used for removing foreign material--either that carried on the raw material, or that resulting from processing operation. Another major wastewater source in the textile industry is the dyeing operation. Exhausted dye baths are generally discharged to the sewers, as are the scouring and rinsing waters used before and after the dyeing operation.

In most of the wet processes, chemicals (generally in an aqueous solution) are brought into contact with the fabrics and are washed or rinsed away; the waste streams that are generated contain a wide variety of pollutants. The principal source of effluent from dry processes is the washing and cleaning of equipment.

For the purposes of establishing effluent guidelines for the textile industry, the following wastewater parameters have been defined to be of major polluting significance: total suspended solids, COD, oil and grease, color, chromium, sulfide, phenol, fecal coliform, and pH. Minor pollution parameters include total dissolved solids, nitrogen, phosphates, temperature (heat), organic chemicals, and heavy metals.

Control Technology and Costs. The technology for control and treatment of waterborne pollutants in the textile industry can be divided into two broad categories: in-process and end-of-pipe. In-process control depends upon two major conditions:

- Altering the processes that generate water pollutants,
- Controlling water use in non-process as well as process areas.

Specific in-process control practices that are applicable to the textile industry include: effective water management and conservation programs; control and containment of leaks and spills; segregation of waste streams; use of "double laced" box washers and counter-current flows to reduce the amount of water used in washing and rinsing operations; use of solvents instead of water as media in processing operations; recycling some wastewater streams; and increased recovery and reuse of processing chemicals.

At present, the textile industry is primarily concerned with end-of-pipe treatment of its wastewaters because most textile wastes are amenable to treatment by biological methods that include activated sludge, trickling filters, anaerobic and aerobic lagoons, and rotating biological contactors. Advanced wastewater treatment methods also applicable to the industry include:

- Phase Change Systems-distillation, freezing.
- Physical Separation Systems-filtration, reverse osmosis, ultrafiltration, electrodialysis.
- Sorption Systems-activated carbon, ion exchange, polymeric adsorption resins.
- Chemical Clarification-chemical coagulation.

The recommended technology for achieving BPT guidelines relies primarily upon the use of biological treatment systems. Recommended technology includes preliminary screening, primary settling (wool scouring only), latex coagulation (carpet mills and dry processing only), and secondary biological treatment. Chlorination is also included for dry processing mills. Strict management control over housekeeping and water use practices is also assumed. BAT guidelines are based upon the above, plus the use of advanced treatment methods such as multi-media filtration and chemical coagulation and clarification following biological treatment. Chlorination is included for all subcategories. NSPS are based on BPT plus the use of multi-media filtration.

Many textile mills already have primary or secondary treatment systems in operation, and they discharge their wastewaters into municipal sewer systems. Data from EPA and from the American Textile Manufacturers Institute indicate that about 35 percent of the water used is now discharged to municipal sewers, 15 percent receives no treatment, 5 percent receives primary treatment, and 45 percent receives secondary treatment.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	$134.0
Incremental BPT O&M	$ 14.8

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associates with these costs. As can be noted, both estimates are within an acceptable range of computational variance. Some minor differences, however, are attributable to different techniques in estimating wasteloads per product unit.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972," National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-10-1.
Textiles
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (1,000 kg/Day)	34,045.	52,093.	55,788.

Annual Growth Rate Over the Period 1976-1985 = 7.37%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	220.52	311.94	330.54
BOD5	186.96	263.08	278.39
COD	1,004.23	1,416.62	1,499.62
Oils and Greases (Wool Scouring only)	52.06	70.36	73.97
Dissolved Solids (Knit, Woven Wool, and Raw Stock only)	.22	.22	.20
Legislated Controls:			
TSS	127.80	60.06	29.54
BOD5	75.01	46.97	43.22
COD	520.04	286.17	195.75
Oils and Greases (Wool Scouring only)	6.36	.31	.17
Dissolved Solids (Knit, Woven Wool, and Raw Stock only)	.06	.01	.01

CONTROL COSTS (Million 1975 $)			AGGREGATED OVER		
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	82.28	(BPT)	85.22	(BAT)	148.81
Pretreatment	40.37		0.00		0.00
New Plants	17.07		198.74		229.37
Municipal Investment Recovery	19.86		169.24		248.68
Totals	159.57		453.21		626.86

Table 4-10-1. (Continued)
Textiles
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	17.49	54.82	57.49	391.11[2]
O&M[3]				
On-site Treatment	2.13	3.47	5.16	32.17
Pretreatment	16.66	25.36	26.61	218.33
Totals	18.79	28.83	31.77	250.50
Municipal Charges				
Investment Recovery	8.81	31.85	32.55	248.68
User Charges[4]	15.09	32.83	34.40	373.02
Totals	23.90	64.68	66.95	621.70
Grand Totals	60.18	148.33	156.22	1,263.31

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Textiles industry includes wool scouring, wool finishing, woven and knit fabric finishing, carpet mills, and stock yarn processes.

BUILDERS PAPER AND ROOFING FELT INDUSTRY

Production Characteristics and Capacities. There were 81 mills in this industry group in 1972. Although there is some overlapping, they are generally divided based upon their announced production as follows:

Dry roofing felt	17 mills
Saturated/coated roofing felt	58 mills
Combination of the above	6 mills

Since mills frequently discontinue old products and introduce new ones, this distribution can only be considered as illustrative.

Builders paper and roofing felt mills are geographically distributed over most of the United States; the majority are located in or near metropolitan areas where the quantity of waste paper required is readily available. As a result of their locations, the majority of the mills (50 - 75 percent) are estimated to be discharging into municipal sewage systems.

Mills in this industry produce building papers and felts as their primary products using wood, waste paper, and rags as raw materials. Although the processes are similar, mills may use different equipment depending upon the raw materials used.

The raw materials are prepared by cooking, beating, and pulping in a blending chest to reduce them to individual fibers. The fibers are then formed on a paper machine and dried by a steam-heated multidrum dryer. Finishing coats are then applied to protect the fibers; the coatings generally consist of mineral fragments in a bitumen or asphalt medium, depending upon each client's specifications.

Building paper products are usually a heavy paper used in construction for support or backing. Roofing felts are usually in shingle or roll form, although sometimes the paper fibers are woven with asbestos to make a roll roofing product of exceptional strength that needs no protective coating.

It is important to note that the percentage of waste paper as a constituent in builders paper and roofing felts is expected to rise from 27.1 percent in 1969 to 40 percent in 1985.

In 1971, a total of 1,469,000 metric tons were produced. Less than 5 percent of total industry output went to foreign markets and imports were also fairly insignificant; this condition is due to the tight supply and demand balance at home. American producers have enjoyed a cost advantage because of cheaper raw material sources. However, this advantage may be eliminated by 1980 because of the European economic community tariffs.

Waste Sources and Pollutants. The sources contributing to the total waste load come from the following:

- The main water use is for cleanup of fiber buildup, fiberizing, and the design function of seal and cooling waters, agitators, and pumps.

- The next largest usage is for emergency make-up water and cooling water for the power boiler, heat exchange condensate, and the asphalt saturation process.

In order to define waste characteristics, the following basic parameters were used to develop guidelines for meeting BPT, BAT, and NSPS: BOD_5, TSS, pH and settleable solids.

Control Technology and Costs. Waste treatment practices in the industry vary according to whether the control is internal or external. Internal waste treatment practices include:

- Reuse of whitewater

- Save all system

- Shower water reduction/reuse

- Gland water reduction/reuse

- Internal spill collection

- Segregation of non-contact process water

- Low volume cooling spray shower nozzles.

External waste treatment practices currently employed in the industry include:

Basic Function	Alternative Technologies
Screening	Traveling, self-cleaning bar screen.
Suspended solids removal	Mechanical clarifier, earthen basin, mixed (multi)-media filtration, coagulation.
BOD5 removal	Aerated stabilization basin, activated sludge storage oxidation ponds.
Temperature control	Cooling tower.

Source: EPA Development Document

BPT guidelines for plants discharging to waterways call for a limitation of BOD5, TSS, settleable solids, and pH by installation of the following treatment technologies:

Internal

- Water showers-self cleaning, low volume, high pressure.
- Segregation of white water systems; maximum reuse within stock preparation machine systems.
- Press water filtering, using vibrating or centrifugal screen.
- Collection systems for vacuum pump/water reduction.
- Control of asphalt spills.

External

- TSS reduction by earthen stilling basin, mechanical clarification, and sludge removal.
- BOD5 reduction using biological oxidation with nutrient addition by activated sludge aerated basins or storage oxidation ponds.
- Secondary solids removal by mechanical clarifiers, stilling ponds, or aquiescent zone in an aerated basin which is beyond the influence of the aeration equipment.
- Sludge disposal by land disposal or incineration.

In addition to the above, BAT guidelines call for the following:

Internal

- Control of spills with a bypass to the retention basin for reuse, discharge into the treatment system or separate treatment.
- Intensive internal reuse of process waters.
- Separation of cooling waters from other wastewater streams with subsequent heat removal and reuse.
- Intensive reduction of gland water spillage.

External

- BOD5 reduction by biological oxidation with nutrient addition.
- Suspended solids reduction by mixed media filtration with, if necessary, chemical addition and coagulation. New Source Performance Standards (NSPS) are the same as BAT for existing plants.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The builders paper and roofing felt industry G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	10.9
Incremental BPT O&M	1.3

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Of the 81 plants covered in both studies, G&P assumes that 75 percent are dumping wastes to municipal treatment systems, and seven percent have no treatment. SEAS assumes that fifty percent dump to municipal systems, with all of the remainder incurring associated BPT costs.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972,"

National Bureau of Economic Research, December, 1975.
(Revised January, 1976)

Table 4-11-1.
Builders Paper & Roofing Felt
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (kkg/Day)	8,987.	11,690.	12,266.

Annual Growth Rate Over the Period 1976-1985 = 4.03%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	64.41	83.94	89.12
BOD5	88.32	115.10	122.21
Legislated Controls:			
TSS	39.17	15.20	8.71
BOD5	41.75	15.28	11.04

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	19.82	(BPT)	93.83	(BAT)	103.46
Pretreatment	0.00		0.00		0.00
New Plants	3.23		16.21		19.93
Municipal Investment Recovery	2.37		18.72		27.54
Totals	25.43		128.76		150.93

Table 4-11-1. (Continued)
Builders Paper & Roofing Felt
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	3.03	17.50	17.84	97.91[2]
O&M[3]				
On-site Treatment	5.80	8.19	15.77	86.06
Pretreatment	0.0	0.0	0.0	0.0
Totals	5.80	8.19	15.77	86.06
Municipal Charges				
Investment Recovery	1.06	3.48	3.54	27.54
User Charges[4]	1.77	2.98	3.03	37.15
Totals	2.83	6.46	6.57	64.70
Grand Totals	11.66	32.15	40.18	248.67

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Builders Paper industry includes heavy construction paper and roofing felts.

PULP, PAPER AND PAPERBOARD INDUSTRY

Production Characteristics and Capacities. The pulp, paper and paperboard industry can be divided into five major subcategories based on the processes involved. The subcategories are:

- Unbleached kraft
- Neutral sulfite semichemical (NSSC) sodium base
- Unbleached kraft and NSSC cross recovery
- Paperboard from waste paper.

The majority of industry production is from unbleached kraft and cross recovery processes. A description of process and product use by subcategories follows:

Unbleached Kraft. Pulp is produced without bleaching using a "full cook" process with a high alkaline-sodium hydroxide and sodium sulfide cooking liquor. Unbleached kraft products are used for linerboard, the smooth facing in corrugated boxes, and grocery sacks.

Sodium Base-Neutral Sulfite Semichemical (NSSC). Pulp production occurs without bleaching, using a neutral sulfite cooking liquor with a sodium base; mechanical fiberizing follows the cooking stage. The main product is the corrugating medium or inner layer in the corrugated box "sandwich."

Ammonia Base-Neutral Sulfite Semichemical (NSSC). Pulp is produced without bleaching, using a neutral sulfite cooking liquor with an ammonia base. Products are similar to sodium base NSSC.

Unbleached Kraft-Neutral Sulfite Semichemical (cross recovery). Unbleached kraft and sodium base NSSC processes are in the same mill. NSSC liquor is recovered within the unbleached kraft recovery process. The products are the same as for the unbleached kraft and NSSC subcategories.

Paperboard from Waste Paper. Paperboard products are produced from a variety of waste papers such as corrugated boxes, box board or newspapers without doing the bleaching, de-inking, or wood pulping operations. Plants classified in this subcategory must obatin at least 80 percent of their fibrous materials from waste paper.

All of the processes are similar in their digestion of wood chips with a chemical cooking liquor and the subsequent removal of the spent liquor. Process differences relate primarily to the preparation, use, and recovery of the cooking liquor. In the case of paperboard, no pulping is involved.

Exports are primarily woodpulp and liner board. American producers have a cost advantage because of cheap raw material sources; however, this advantage may be eliminated by the European Economic Community tariff increases scheduled for 1980. (Europe comprises 43 percent of the export market.) Imports of pulp, paper, and paperboard products are not significant.

Waste Sources and Pollutants. The main sources contributing to the total waste load come from the following processes: wood preparation, pulping processes and the paper machine.

In order to define waste characteristics, the following basic parameters were selected as guidelines for meeting BPT and BAT: BOD_5, TSS, pH, and color.

Control Technology and Costs. Waste treatment practices in the pulp, paper and paperboard industry include the following methods.

- Reuse of gland, vacuum pump seal, knot removal shower, wash and condensate waters
- Internal spill collection: hot stock screening and chemical and dregs recovery
- Land disposal: save all systems
- Screening and neutralization
- Suspended solids removal by mechanical clarifier, earth basin, filtration and dissolved air flotation
- BOD_5 removal by aerated stabilization basin, activated sludge and storage control
- Form control by chemical and mechnical means
- Color removal by lime treatment, activated carbon, coagulation-alum, and reverse osmosis
- Resin adsorption, ultra-filtration, amino treatment and ion flotation.

The technology called for in BPT, BAT and NSPS guidelines are summarized as follows:

Guideline and Area	Subcategories	Technology Called For
BPT Internal	Unbleached Kraft	Hot stock screening, spill and evaporator boil-out storage, multi-stage counter current washers
	Sodium base-NSSC	Non-polluting spent liquor disposal by (a) partial evaporation/incineration (b) fluidized bed reactor
	Ammonia base-NSSC	Non-polluting spent liquor disposal by partial evaporation/incineration
	Unbleached Kraft-NSSC	Hot stock screening, spin and evaporator boil-out storage, efficient pulp washing
	Paperboard	TSS reduction by earthen basin, mechanical clarification and sludge removal, and dissolved air flotation
BPT External	All Subcategories	
		TSS reduction by: earthen basin mechanical clarification and sludge removal, and dissolved air flotation
		BOD_5 reduction by: activiated sludge, aerated stablilzation basins, storage oxidation ponds
		Biological solids removal by: mechanical clarifiers, stilling ponds, stilling pond with an aerated stabilization basin, or quiescent zone in an aerated stabilization basin beyond the influence of aeration equipment
		Sludge disposal by landfilling or incineration

Guideline and Area	Subcategories	Technology Called For
BPT Paper Machines	All Subcategories	
		Water Showers
		Segregation of white water
		Press water filtering by vibrating or centrifugal screen
		Collection system for vacuum pump seal water
		Gland water reduction
BAT Internal	All Subcategories	
		Reuse of fresh water filter backwash
		Control of spills-retention, reuse or separate treatment
		Reduction of pulp wash and extraction water
		Internal reuse of process waters
		Separate cooling, waters from the other wastewater streams-treat, removal, and reuse
		Reduction of gland water spillage

BAT External	All Subcategories	BOD_5 reduction by: biological oxidation with nutrient addition. TSS reduction by: mixed media filtration and chemical addition and coagulation color reduction-minimum lime treatment for cross recovery mills and reverse osmosis for NSSC both sodium and ammonia base

Guideline and Area	Subcategories	Technology Called For
NSPS	All Subcategories	Coagulation and filtration not included for any subcategories, color reduction for both NSSC bases are not included. Same as BAT, no real process changes but changes to increase efficiency.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

	Total	Phase I	Phase II
Incremental BPT Investment	$2,045.1	369.2	1,675.9
Incremental BPT O&M	$ 189.8	49.3	140.5

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with thses costs. Principal reasons for differences between these cost estimates and the newer data are estimates of the distribution of costs between model plant sizes, as well as basic costs associated with a particular model plant.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries

of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-12-1.
Pulp, Paper, and Paperboard Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity:			
Phase I (MT/Day)	64,114.	83,675.	88,032.
Phase II (MT/Day)	128,020.	186,760.	202,140.

Annual Growth Rate Over the Period 1976-1985:
Phase I = 4.22%
Phase II = 6.13%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	901.44	1,276.82	1,378.35
BOD5	880.17	1,234.30	1,329.73
Legislated Controls:			
TSS	571.34	282.10	173.70
BOD5	399.98	179.66	138.13

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Phase I					
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	182.72	(BPT)	666.22	(BAT)	751.61
Pretreatment	0.00		0.00		0.00
New Plants	16.55		189.32		220.11
Municipal Investment Recovery	1.32		10.02		14.76
Totals	200.59		865.56		986.48

Table 4-12-1. (Continued)
Pulp, Paper, and Paperboard
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Phase I (Continued)				
Annualized Costs	1977	1983	1985	1976-85
Annaulized Capital[1]	26.20	138.68	142.54	824.03[2]
O&M[3]				
On-site Treatment	47.85	88.73	156.44	783.71
Pretreatment	0.0	0.0	0.0	0.0
Totals	47.85	88.73	156.44	783.71
Municipal Charges				
Investment Recovery	0.58	1.86	1.90	14.76
User Charges[4]	0.94	1.62	1.66	19.91
Totals	1.51	3.48	3.56	34.67
Grand Totals	75.56	230.89	302.54	1,642.42

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Pulp and Paper (Phase I) industry includes unbleached kraft, NSSC, and paperboard from waste products.

Table 4-12-1. (Continued)
Pulp, Paper, and Paperboard
Industry Data Summary

CONTROL COSTS (Million 1975 $)			AGGREGATED OVER	
Phase II				
Investment	1974-77		1978-83	1976-85
Existing Plants				
On-site Treatment	847.12	(BPT)	2,473.44	(BAT) 2,846.42
Pretreatment	0.00		0.00	0.00
New Plants	126.61		993.03	1,204.70
Municipal Investment Recovery	99.27		800.81	1,178.53
Totals	1,073.00		4,267.28	5,229.64

		COST IN YEAR		
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	128.02	583.77	608.26	3,527.68[2]
O&M[3]				
On-site Treatment	109.46	208.86	453.43	2,142.67
Pretreatment	0.0	0.0	0.0	0.0
Totals	109.46	208.86	453.43	2,142.67
Municipal Charges				
Investment Recovery	44.07	149.75	152.83	1,178.53
User Charges[4]	74.47	143.82	151.80	1,685.63
Totals	118.54	293.57	304.63	2,864.15
Grand Totals	356.02	1,086.20	1,366.33	8,534.50

Table 4-12-1. (Continued)
Pulp, Paper, and Paperboard
Industry Data Summary

Phase II (Continued)

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Pulp and Paper (Phase II) industry includes bleached kraft, sulfite processes, soda and groundwood processes, deinked processes, and non-integrated processes.

PLYWOOD, HARDBOARD, AND WOOD PRESERVING INDUSTRY

Production Characteristics and Capacities. The plywood, hardboard, and wood preserving segment of the timber products processing industry is a large and complex conglomerate. For purposes of establishing effluent limitations guidelines, and standards of performance, it has been divided into eight subcategories as follows: (1) barking, (2) veneer, (3) plywood, (4) hardboard - dry process, (5) hardboard - wet process, (6) wood preserving, (7) wood preserving - steam, and (8) wood preserving - boultonizing.

There were 916 operating plants in 1973 comprising the plywood, hardboard, and wood preserving segments of the timber industry.

Barking includes the operations that remove the bark from logs, either through mechanical abrasion or by hydraulic force. Veneer includes converting barked logs or heavy timber into thinner sections of wood, which may be later cut and conditioned to improve its quality. Plywood includes operations of laminating layers of veneer to form finished plywood, either softwood from veneers of coniferous or needle bearing trees or hardwood from deciduous or broad-leaf trees. Hardboard includes the operations leading to the production of panels from chips, sawdust, logs, or other raw materials, using either the dry (air) or wet (water) matting processes for forming the board mat. Wood processing includes all pressure or non-pressure processes employing water-borne salts (copper, chromium, or arsenic), in which steaming or vapor drying is not the predominant method of conditioning. Wood preserving-steam includes steam impingement on the wood being conditioned. Wood preserving-boultonizing uses a vacuum extraction of water as the conditioning method. Timber products are used primarily for the building and construction industry, commercial uses, and home and decorative purposes.

Waste Sources and Pollutants. Wastewater sources are given for the following segments:

- Barking. Hydraulic barking contributes high suspended solids and BOD, as does drum barking.

- Plywood and veneer. Log conditioning, cleaning of veneer dryers, washing of the glue lines and glue tanks, and cooling water.

- Hardboard. Wastewater discharge is low for dry processing but can occur due to washing. Sources from wet processing include: raw materials handling, fiber and mat formation, and processing.

- Wood preserving. Oils, simple sugars, cooling water, steam condensate, boiler blowdown.

The major pollutant parameters common to all subcategories, but not necessarily present in process water from all the categories for which effluent guidelines and standards are presented, include the following: BOD_5, COD, phenols, oil and grease, pH, high temperature, dissolved solids, total suspended solids, phosphorus, and ammonia.

Wood preserving subcategories may also include the following pollution contributors: copper, chromium, arsenic, zinc, and flourides. The above pollutants or pollutant parameters are not always present in process water from all the subcategories, and their presence depends on the processing methods.

Presently, 20 to 30 percent of the veneer and plywood plants are achieving the no discharge limitations. About 25 percent of the hardboard manufacturers and from 5 to 10 percent of the wood preserving plants are also achieving the no discharge limitations.

Control Technology and Costs. Current technology includes the following:

- Barking. Clarifiers.

- Veneer. Reduce amount of wastewater by reuse and conservation.

- Plywood. Minimal wastewater reduction in water use.

- Hardboard-Dry. Oil and water separation, waste retention ponds or spray irrigation.

- Hardboard-Wet. Water recycle, filtration, sedimentation, coagulation, evaporation, and biological oxidation such as lagoons, aerated lagoons, and activated sludge systems.

- Wood Preserving. Storage or discharge to sewers, evaporation and incineration, flocculation and sedimentation.

BPT includes the following:

- Barking. Primary screening and settling followed by biological treatment.

- Veneer. Substituting for direct steam conditioning of logs: hot water spray tunnels, indirect steaming, or modified steaming with the use of steam coils. Irrigation of solid waste.

- Plywood. Use of steam to clean spreaders where applicable and the use of high pressure water for cleaning, use of glue applicators that spray water for glue makeup, and evaporation and spray application of glue water on bark going to the incinerator.

- Hardboard-Dry. Recycle of log wash and chip wash water and disposal of the solids by landfill or use as boiler fuel, operation of the resin system as a closed system with wash water being recycled, and spray irrigation of solids.

- Hardboard-Wet. Recycle of process water as dilution water, utilization of heat exchanges to reduce temperature and gravity settling, screening, filtration or floatation to reduce suspended solids, primary settling plus screening followed by aerated lagoons or activated sludge or both with pH adjustment, and disposal of sludge by aerobic digestion in sludge lagoons, recycle or as landfill.

- Wood Preserving. Recovery of contaminated water, modifications of existing non-pressure processing equipment, oil recovery equipment, and biological treatment.

BAT consists of the following:

- Barking. Reduction in water use and recycle.

- Veneer. Use of dry veneer dryer cleaning methods or proper land disposal.

- Plywood. Elimination of discharge from gluing operation and dry housekeeping procedures.

- Hardboard-Dry. Same as BPT.

- Hardboard-Wet. Installation of a pre-press and evaporation system, primary treatment followed by biological treatment, and recycle.

- Wood Preserving. Implementation of good housekeeping practices, and minimizing water use.

NSPS is the same as BPT for barking, and the same as BAT for the remaining processes in the industry.

Annualized control costs are detailed in Table 4-13-1.

Table 4-13-1.
Plywood, Hardboard, and Wood Preserving
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity:			
Plywood & Veneer (Million Sq. M/Day)	2,121.	2,595.	2,534.
Wood Preserving (Liter/Day)	3,811,109.	4,662,812.	4,552,324.
Hardwood (kkg/Day)	5,125.	7,494.	7,316.

Annual Growth Rate Over the Period 1976-1985 = 3.22%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985

Note: Residual data not available at time of Report issue.

1971 Controls:

Legislated Controls:

CONTROL COSTS (Million 1975 $)		AGGREGATED OVER	
Investment	1974-77	1978-83	1976-85
Existing Plants			
On-site Treatment	66.24 (BPT)	16.43 (BAT)	44.26
Pretreatment	0.00	0.00	0.00
New Plants	5.12	26.46	26.63
Municipal Investment Recovery	0.0	0.0	0.0
Totals	71.36	42.89	70.89

Table 4-13-1. (Continued)
Plywood, Hardboard, and Wood Preserving Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	9.38	15.02	15.04	122.81[2]
O&M[3]				
On-site Treatment	22.93	32.34	38.76	302.33
Pretreatment	0.0	0.0	0.0	0.0
Totals	22.93	32.34	38.76	302.33
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	32.31	47.36	53.80	425.14

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Plywood, Hardboard and Wood Preserving industry includes softwood and hardwood plywood and veneer processing, wet and dry hardboard, and preserving processes.

INORGANIC CHEMICALS INDUSTRY

Production Characteristics and Capacities. The complex and heterogeneous inorganic chemicals industry produces thousands of chemicals. Each of the chemicals covered by the effluent guidelines is manufactured by one or more processes, most of which are covered by the current guidelines. Because the various products and processes differ considerably from one another, it is not possible to describe them in detail. Generally, they can be said to involve the chemical reaction of raw materials, followed by the separation, collection, and purification of the product. Table 4-14-1 identifies each of the processes covered and summarizes briefly the raw materials used and the nature of each process.

Table 4-14-1.
Inorganic Chemicals
Industry Products and Processes

Product (Use)	Processes Covered by Phase I Effluent Limitations Guidelines	Raw Materials	Description
Aluminum chloride (catalyst in petrochemical and plastics industry)	All	Gaseous chloride, molten aluminum	Chloride introduced below surface of aluminum, product sublimes and is selected by condensation. Produces anhydrous aluminum chloride.
		Bauxite, coke, chlorine	
		Hydrated aluminum or bauxite ore; hydrochloric acid	
Aluminum sulfate (water purification)	All	Bauxite ore or other aluminum compound, concentrated sulfuric acid	Ground ore and acid reacted in a digester. Muds and insolubles settled and filtered out.
Calcium carbide (manufacture of acetylene)	Uncovered furnaces only	Limestone; coke, petroleum coke or anthracide	Limestone and carbon reacted in a furnace.
Calcium chloride (deicing and dust control on roads, stabilizer in pavement and cement)	Brine extraction	Salt brines or solvay process waste liquor	Brines cocentrated and purified; then evaporated to yield product which is flaked and calcined to yield a dry acid.
Calcium oxide and calcium hydroxide (lime) (many chemical and industrial uses)	All	Limestone	Limestone heated in a kiln.
Chlorine and sodium or potassium hydroxide (chlor-alkali) (many industrial uses)	Mercury cell diaphragm cell	Sodium chloride or potassium chloride brines	Brines purified, then electrolyzed. Products collected at electrodes and purified.
Hydrochloric acid (many industrial and chemical uses, particularly pickling of steel)	Direct chlorine-hydrogen reaction	Chlorine, hydrogen	Hydrogen and chlorine gases reacted in a vertical burner. Acid is cooled and absorbed in water.

Source: EPA Development Document.

Table 4-14-1. (Continued)
Inorganic Chemicals
Industry Products and Processes

Product (Use)	Processes Covered by Phase I Effluent Limitations Guidelines	Raw Materials	Description
Sodium carbonate (soda ash) (glass and non-ferrous metals, other products)	Solvay process	Ammonia; salt brine; carbon dioxide	Sodium bicarbonate produced from reacting the raw materials in an aqueous solution. This is then converted to soda ash by heating.
Sodium chloride (table salt)	Solar evaporation	Salt water	Salt water concentrated by evaporation in open ponds. The brine is then crystallized wherein sodium chlorine precipitates.
	Solution brinemining	Water; salt deposits	Water pumped into an underground salt deposit. Brine pumped out and purified. Product crystallized out.
Sodium dichromate (manufacturing of pigments, other industrial uses, corrosion inhibition)	All	Chrome ore; sodium carbonate; lime; sulfuric acid	Raw materials calcinated, then leached. Soluble chromates converted to dichromates with sulfuric acid. Dichromates crystallized out.
Sodium metal (manufacture of tetraethyl lead and other products; nuclear coolant)	Downs cell process	Sodium chloride; alkali fluorides; calcium chloride	Mixture melted and electrolyzed. Sodium collected at cathode.
Sodium silicate (manufacture of silica gel)	All	Caustic soda; silica	Caustic soda and silica sand mixed, then charged in a furnace. Water and steam added to dissolve the silicate. Silicate evaporated.
Sodium Sulfite (bleaching; food preservative; boiler feed water additive)	Reaction of sulfur dioxide and soda ash	Sulfur dioxide gas; sodium carbonate (soda ash)	Gas passed into a soda ash solution. Solution heated. Sulfate is purified, filtered, crystallized.

Source: EPA Development Document.

Table 4-14-1. (Continued)
Inorganic Chemicals
Industry Products and Processes

Product (Use)	Processes Covered by Phase I Effluent Limitations Guidelines	Raw Materials	Description
Hydrofluoric acid (production of fluorinated organics and plastics, etc.)	All	Sulfuric acid, fluorspar	Materials reacted in a furnace, acid cooled and absorbed in water, then redistilled.
Hydrogen peroxide (bleaching agent)	Electrolytic process	Ammonium (or other) bisulfate; water	Bisulfate electrolyzed to persulfate, which is then reacted with water.
	Organic process	Alkyl anthraquinone; hydrogen; oxygen	Alkylanthraquinone reduced by hydrogen over a catalyst, then oxidized in a forced gas stream to produce the original alkylanthraquinone and hydrogen peroxide.
Nitric acid (fertilizers, explosives)	Only concentrations up to 66% by weight. Reaction of sodium nitrate and sulfuric acid not included.	Ammonia; air; water	Ammonia oxidized over a catalyst to form nitrogen dioxide which is reacted with water under pressure to form the product.
Potassium metal (used in organo-potassium compounds and in sodium-potassium manufacture)	All	Potassium chloride; sodium vapor	Potassium chloride melted, then exposed to sodium vapors in an exchange column.
Potassium dichromate (glass pigment and photographic development)	All	Sodium dichromate; potassium chloride	Potassium chloride added to a dichromate solution. Product crystallized out.
Potassium sulfate (agriculture)	All	Langbeinite; potassium chloride	Potassium chloride added to a solution of crushed langbeinite. Product percipitated out.
Sodium bicarbonate (baking soda) (wide variety of uses including food processing and manufacturing)	All	Sodium carbonate; water; carbon dioxide	Materials reacted under pressure. Product precipitated.

Source: EPA Development Document.

Table 4-14-1. (Continued)
Inorganic Chemicals
Industry Products and Processes

Product (Use)	Processes Covered by Phase I Effluent Limitations Guidelines	Raw Materials	Description
Sulfuric acid (fertilizer, petroleum refining, explosives, others)	Contact process (single and double absorption)	Sulfur	Sulfur burned to yield sulfur dioxide, mixed with air, heated, and then introduced into a catalytic converter to produce sulfur trioxide. This gas is then cooled and absorbed in a sulfuric acid solution.
Titanium dioxide (white pigment in paint, ink, and other products)	Chloride process	Titanium dioxide ores; chlorine; coke	Chlorination of ores produces titanium tetrachloride, which is then oxidized to form the product.
	Sulfate process	Titanium dioxide ores; sulfuric acid	Ores dissolved in sulfuric acid at high temperatures to produce titanium sulfate which is hydrolyzed to form a hydrate. This is then calcined to form the product.

Source: EPA Development Document.

Production capacity of some of the chemicals is concentrated in the hands of a few producers; in the case of potassium dichromate, there is only one. The market for other products is much more competitive; for example, there are over 100 producers of lime. The total production of the inorganic chemicals covered by the Phase I effluent limitations guidelines was about 139 million tons in 1971. Of this total production, about 48 million tons or 34 percent actually come within the control of the guidelines. The remaining 66 percent is comprised of chemicals which are either produced by processes not covered by the guidelines or are produced in plants that are classified as other industries, such as pulp mills and steel mills.

Waste Sources and Pollutants. Water is used in inorganic chemical manufacturing plants for three principal purposes:

- Cooling. Non-contact cooling water.
- Process. Contact cooling or heating water, contact wash water, transport water, product and dilution water.
- Auxiliary water.

The effluent limitations guidelines apply to process wastewater pollutants only. This includes those wastewater constituents in water which directly contact the product, byproduct, intermediate, raw material, or waste product. Examples are waters used for barometric condensers, contact steam drying, steam distillation, washing of products, intermediates or raw materials; transporting reactants or products in solution, suspension or slurry form; and water which becomes an integral part of the product or is used to form a more dilute product.

The following basic pollutant parameters are covered in the effluent limitations guidelines for the inorganic chemicals industry: total suspended solids (TSS), cyanide, chromium, chemical oxygen demand (COD), iron, lead, mercury, total organic carbon (TOC), and pH.

Control Technology and Costs. The manufacture of some of the inorganic chemicals covered by the effluent limitations guidelines produces no waterborne wastes. In these cases, the only control technology required is the isolation, handling, and often reuse of water from leaks, spills, and washdowns. The most common wastewater treatment practices in the remainder of the industry are neutralization, the settling of suspended solids in ponds, storage, and discharge of the neutralized and clarified effluent to surface waters. Deep-well disposal is also used, particularly for sodium chloride brine-mining waters. When more control is necessary because of the presence of harmful wastes, more advanced technology, such as ion exchange and chemical reduction and precipitation, is employed. In-process control measures commonly employed include monitoring techniques, safety practices, good housekeeping, containment provisions, and segregation practices.

Table 4-14-2 summarizes the control techniques associated with BAT and BPT guidelines. BPT assumes the normal use of practiced in-process controls, such as recycling and alternative use of water, and recovery and/or reuse of wastewater constituents. BAT assumes the highest degree of in-process controls that are available and are economically achieveable.

New source performance standards (NSPS) are the same as BPT for all chemicals except chlorine (chlor-alkalis), sodium dichromate, and titanium dioxide. For chlorine, metal anodes may be used to eliminate lead discharges. For both chlorine and sodium dichromate, NSPS guidelines assume decreased water discharges based upon improved water processing designs in new plants. NSPS for titanium dioxide are the same as BAT.

Table 4-14-2.
Inorganic Chemicals
Industry Summary of Control Technologies

Chemical	Best Practicable Technology (BPT)	Best Available Technology (BAT)
Aluminum chloride (anhydrous)	No water scrubbers for white or grey aluminum chloride production. For yellow aluminum chloride production, gas scrubbing and sale of scrubber wastes as aluminum chloride solution, or Gas scrubbing followed by chemical treatment to precipitate aluminum hydroxide and recycle	Same as BPT
Aluminum sulfate	Settling pond and reuse	Same as BPT
Calcium carbide	Dry dust collection system	Same as BPT
Hydrochloric acid chlorine burning	Acid containment and isolation with centralized collection acid wastes and reuse	Same as BPT
Hydrofluoric acid	Acid containment and isolation, and reuse	Same as BPT
Sodium bicarbonate	Evaporation and product recovery, or Recycle to process	Same as BPT
Sodium chloride (solar process)	Good housekeeping to prevent contamination of waste salts	Same as BPT
Sodium silicate	Storage of wastes in an evaporation pond, or Ponding and clarification	Ponding or clarification and recycle of treated wastewater

Table 4-14-2. (Continued)
Inorganic Chemicals
Industry Summary of Control Technologies

Chemical	Best Practicable Technology (BPT)	Best Available Technology (BAT)
Sulfuric acid (sulfur burning contact process)	Acid containment and isolation with recycle to process or sell as weak acid	Same as BPT
Lime	Dry Bag Collection Systems, or Treatment of scrubber water by ponding and clarification and recycle	Same as BPT
Nitric acid	Acid containment and isolation and reuse	Same as BPT
Potassium (metal)	No process water used in manufacture	Same as BPT
Potassium dichromate	Replacement of barometric condensers with non-contact heat exchangers; recycle of process liquor	Same as BPT
Potassium sulfate	Evaporation of brine waters with recovery of magnesium chlorine, or Reuse of brine solution in process in place of process water	Same as BPT
Calcium chloride (brine extraction)	Settling pond or clarification	Same as BPT plus replacement of barometric condensers with non-contact heat exchangers and additional recycle
Hydrogen peroxide (organic)	Isolation and containment of process wastes; oil separation and clarification	Chemical decomposition for peroxide removal and carbon adsorption for organic removal
Sodium (metal)	Salting pond, and Partial recycle of brine waste solution after treatment	100% brine recycle and reuse or sale of spent sulfuric acid

Table 4-14-2. (Continued)
Inorganic Chemicals
Industry Summary of Control Technologies

Chemical	Best Practicable Technology (BPT)	Best Available Technology (BAT)
Sodium chloride (solution mining)	Containment and isolation of spills, packaging wastes, scrubbers, etc; partial recycle to brine cavity	Same as BPT plus replacement of barometric condensers with non-contact heat exchangers
Sodium sulfite	Air oxidation of sodium sulfite wastes to sodium sulfate--94% effective, and final filtration to remove suspended solids	Same as BPT plus recovery of waste sodium sulfate
Soda ash (sodium carbonate) Solvay Process	Settling ponds	Settling ponds and clarification
Hydrogen peroxide (electrolytic)	Ion exchange to convert sodium ferrocyanide to ammonium ferrocyanide which is then reacted with hypochlorite solution to oxidize it to cyanate solutions, and Settling pond or filtration to remove catalyst and suspended solids	Same as BPT plus segregation of wastewater from cooling water and evaporation of the waste stream and recycle of the distillate
Sodium dichromate and sodium sulfate	Isolation and containment of spills, leaks, and runoff, and Batchwise treatment to reduce hexavalent chromium to trivalent chromium with NaHS, plus precipitation with lime or caustic; and Settling pond with controlled discharge	Same as BPT plus evaporation of the settling pond effluent with recycling of water and land disposal or recovery of solid waste
Chlor-alkali (diaphragm cell)	Asbestos and cell rebuild wastes are filtered or settled in ponds then land dumped, and Chlorinated organic wastes are incinerated or land dumped, and Purification muds from brine purification are turned to salt cavity or sent to evaporation pond/settling ponds, and Weak caustic-brine solution from the caustic filters is partially recycled	Same as BPT plus: Reuse or sell waste sulfuric acid Catalytic treatment of the hypochlorite waste and reuse or recovery Recycle of all weak brine solutions Conversion to stable anodes

Table 4-14-2. (Continued)
Inorganic Chemicals
Industry Summary of Control Technologies

Chemical	Best Practicable Technology (BPT)	Best Available Technology (BAT)
Chlor-alkali (mercury cell)	Cell rebuilding wastes are filtered or placed in settling pond, then used for landfill, and Chlorindated organic wastes are incinerated or placed in containers and land dumped, and Purification muds from brine purification are returned to brine cavity or sent to evaporation/settling ponds, and Partial recycle of brine waste streams, and	Same as BPT plus: Reuse or recovery of waste sulfuric acid Catalytic treatment of the hypochlorite waste and reuse or recovery Recycle of all weak brine solutions
Chlor-alkali (mercury cell) (continued)	Recovery and reuse of mercury effluent by curbing, insulation and collection of mercury containing streams, then treatment with sodium sulfide	
Titanium dioxide (chloride process)	Neutralization with lime of caustic, and Removal of suspended solids with settling ponds or clarifier-thickener, and Recovery of byproducts	Same as BPT plus additional clarification and polishing
Titanium dioxide (sulfate process)	Neutralization with lime or caustic, and Removal of suspended solids with settling ponds or clarifier-thickener, and Recovery of byproducts	Same as BPT plus additional clarification and polishing

Source: EPA Development Document

The most recent analysis of costs for this sector was provided to the Agency by Arthur D. Little, Inc. (ADL)[1]. This analysis was conducted in somewhat greater depth than, and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure, and is considered to be more precise. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The estimates are as follows, for comparable portions of industry (in million 1975 dollars):

	ADL	SEAS
Incremental BPT Investment	$210.6	180.3

SEAS and ADL give investment figures for only 11 chemicals in common. There is a substantial difference in segments of the industry covered by the two studies. The split between BPT and BAT costs for treatment of chemical production varies considerably for these chemicals associated with these costs is extremely close in most instances. As an example, titanium dioxide (sulfate process) was investigated by both studies with associated investment costs forecast as follows (in millions 1975 dollars):

	BPT	BAT
ADL	14.0	2.1
SEAS	15.6	0.4

For Phase II chemicals, there is not any consistency for model plant costs of the two studies.

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[1] "Economic Analysis of Proposed Effluent Guidelines - Inorganic Chemicals, Alkaline and Chlorine Industries (Major Products)", Arthur D. Little, Inc., August, 1973. "Economic Analysis of Proposed Effluent Guidelines for the Inorganic Chemicals Industries, Phase II", Arthur D. Little, Inc., Sept., 1974.

Table 4-14-3.
Inorganic Chemicals
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity:			
Phase I (kkg/Day)	235,010.	325,950.	350.200
Phase II (kkg/Day)	623.	930.	1,013

Annual Growth Rate Over the Period 1976-1985:
Phase I = 5.26%
Phase II = 6.65%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	106.81	110.36	105.04
BOD5	43.01	60.67	65.49
COD	165.07	230.43	248.16
Dissolved Solids	5,103.18	5,232.25	4,965.65
Acids	293.06	325.76	324.07
Legislated Controls:			
TSS	32.74	4.78	3.03
BOD5	15.48	5.39	4.44
COD	91.76	53.86	40.32
Dissolved Solids	4,419.02	1,292.80	383.07
Acids	75.57	.01	0

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER		
Phase I			
Investment	1974-77	1978-83	1976-85
Existing Plants			
On-site Treatment	201.64 (BPT)	198.09 (BAT)	282.88
Pretreatment	0.00	0.00	0.00
New Plants	21.98	115.48	143.25
Municipal Investment Recovery	0.0	0.0	0.0
Totals	223.62	313.57	426 14

Table 4-14-3. (Continued)
Inorganic Chemicals
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Phase I (Continued)				
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	29.40	70.63	73.27	499.86[2]
O&M[3]				
On-site Treatment	92.72	99.84	120.62	1,008.39
Pretreatment	0.0	0.0	0.0	0.0
Totals	92.72	99.84	120.62	1,008.39
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	122.12	170.47	193.89	1,508.25

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The phase I Inorganic chemicals industry includes aluminum sulfate, calcium chloride, mercury cell-chlor alkali, mercury cell-diaphragm, hydrochloric acid, hydrogen peroxide, nitric acid, potassium dichromate, potassium sulfate, sodium carbonate, sodium chloride, sodium dichromate, sodium metal, sodium silicate, sodium sulfite, sulfuric acid, titanium dioxide, and lime.

Table 4-14-3. (Continued)
Inorganic Chemicals
Industry Data Summary

CONTROL COSTS (Million 1975 $)			AGGREGATED OVER		
Phase II					
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	4.71	(BPT)	11.58	(BAT)	13.91
Pretreatment	0.00		0.00		0.00
New Plants	1.58		7.87		10.15
Municipal Investment Recovery	0.0		0.0		0.0
Totals	6.30		19.45		24.06

	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	0.83	3.39	3.57	21.56[2]
O&M[3]				
On-site Treatment	0.37	0.74	1.58	7.37
Pretreatment	0.0	0.0	0.0	0.0
Totals	0.37	0.74	1.58	7.37
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	1.20	4.13	5.16	28.93

Table 4-14-3. (Continued)
Inorganic Chemicals
Industry Data Summary

Phase II (Continued)

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Phase II Inorganic Chemicals industry includes calcium carbonate, chrome pigments and iron blues, and potassium permanganate.

FERTILIZER CHEMICALS INDUSTRY

Production Characteristics and Capacities. The fertilizer industry can be divided into phosphate and nitrogen fertilizer production areas, containing a total of 11 subcategories:

1. Phosphate Fertilizers
    - Phosphate rock grinding
    - Wet process phosphoric acid
    - Phosphoric acid concentration
    - Normal superphosphate (NSP)
    - Triple superphosphate (ISP)
    - Ammonium phosphates
    - Sulfuric acid

2. Nitrogen Fertilizers
    - Ammonia
    - Urea
    - Ammonium nitrate
    - Nitric acid

These subcategories include both mixed and non-mixed fertilizers.

The manufacture of these fertilizers involves a variety of chemical processes. Three of the processes - phosphate rock grinding, phosphoric acid concentration, and phosphoric acid clarification - do not require process waters. The remaining processes are summarized in Table 4-15-1.

Table 4-15-1.
Basic Fertilizer Chemicals Manufacturing Process

Product	Raw Material	Process
Wet process Phosphoric acid	Phosphate rock, sulfuric acid, water.	Mixing.
Normal superphosphate	Sulfuric acid, ground phosphate rock, water.	Mixing, curing for 3-8 weeks.
Triple superphosphate	Ground phosphate rock, phosphoric acid, water.	Run of pile process=mixing curing. or Granular triple superphosphate process (GTSP)= mixing into a slurry, drying.
Ammonium phosphates	Ammonia, wet process, phosphoric acid.	Similar to GTSP above.
Sulfuric acid	SO_2, O_2, pellitized vanadium oxide catalyst, water.	Acid buring process SO_2 % O_2 catalyzed to form SO_3, water added to form final product.
Ammonia	Natural gas or other hydrogen source, air, activated carbon, catalysts.	Hydrogen production followed by catalysis with air to form ammonia.

Table 4-15-1. (Continued)
Basic Fertilizer Chemicals Manufacturing Process

Product	Raw Material	Process
Urea	Ammonia, sulfur dioxide.	Ammonium carbonate formed then dehydrated by prilling or crystallization to form urea.
Ammonium nitrate	Ammonia, nitric acid.	Combined in a neutralized acid, then prilled or neutralized to concentrate the product.
Nitric acid	Ammonia, air, water, platinum-rhodium gauze catalyst.	Ammonia and air oxidized, absorbed in water, then catalyzed.

Sulfuric acid and nitric acid are intermediate products in the basic fertilizer chemicals industry. Approximately 25 percent of the plants produce these chemicals as part of the production of the final products listed above; they are not considered as separate plants for the purposes of this report. Plants which produce sulfuric acid or nitric acid as end products are covered under the inorganic chemicals industry.

In terms of retail value, exports amounted to approximately 12.5 percent of domestic production, and imports 7 percent. By weight, exports totaled a considerably higher proportion of production, approximately 45 percent (171 million metric tons). Of this, phosphate rock comprised the largest portion, 13.6 million metric tons. With the exception of ammonium nitrates, the United States is a net exporter of all the fertilizers covered in this study.

Because fertilizers are traded in a world-wide market, and the raw materials used are also used in a wide variety of markets, the fertilizer market is subject to many outside influences. These influences include world-wide agricultural demand, the use of nitrates in explosives, and hence pressures from the international military situation, and the world market for synthetic fibers.

In 1972, the fertilizer industry was suffering from overcapacity with no new plants being built. However, in 1973, world demand increased so dramatically that substantial shortages were created in the industry.

Projections published by the National Fertilizer Development Center of the Tennessee Valley Authority indicate that the shortages in supply of phosphate materials will be alleviated as significant surpluses develop by 1976 or 1977. The nitrogen shortage is expected to continue longer, with a balanced market developing in the late 1970's.

Waste Sources and Pollutants. The major fertilizer waste components include the following: pH, phosphorous, fluorides, total suspended solids (TSS), ammonia, total dissolved solids (TDS), high temperature, cadmium, total chromium, zinc, vanadium, arsenic, uranium, Radium 226, COD, oil and grease, ammonia nitrogen, organic nitrogen, nitrate nitrogen, iron, and nickel.

The main waste sources contributing to the total waste load can be identified as coming from the following processes in each production area:

Phosphate Fertilizers

- Water treatment plant effluent including raw water, filtrations, clarification, water softening, and water deionization.
- Closed-loop cooling tower blowdown.
- Boiler blowdown.
- Contaminated water (gypsum pond water).
- Make-up water.
- Spills and leaks.
- Nonpoint source discharges including surface waters from rain or snow that become contaminated.

Nitrogen Fertilizers

- Water treatment plant effluent including raw water filtration and clarification, water softening, and water deionization.
- Closed-loop cooling tower blowdown.

- Boiler blowdown.
- Process condensate.
- Spills and leaks that are collected in pits or trenches.
- Nonpoint sources collected from rain or snow.

In order to define waste characteristics, the following basic parameters were used to develop guidelines for meeting BPT and BAT: Phosphate Fertilizers: phosphorous, fluorides, total suspended solids and pH. Nitrogen Fertilizers: ammonia, organic nitrogen, nitrate, and pH.

Control Technology and Costs. Waste treatment practices in the fertilizer industry include: monitoring units, retaining areas, cutoff impoundments, reuse, recycle, atmospheric evaporative cooling, double-lining, two-stage lime neutralization, surrounding dikes and seepage collection ditches, sulfuric acid, dilution with pond water, evaporation, ammonia stripping (steam and air), high pressure air/steam stripping, urea hydrolysis, nitrification and denitrification, ion exchange, cation/aniou separation unit, selective ion exchange for ammonia removal, oil separation and ammonium nitrate condensate reuse.

BPT guidelines for the phosphate segment call for limitations on pH, TSS, phosphates, and florides by installing the following: double-lime treatment of gypsum pond water, pond design to contain a 10-year storm, monitoring system for sulfuric acid plant control, and facilities for contaminated water isolation. BPT guidelines for the nitrogen segment can be met by installing the following: ammonia steam stripping, urea hydrolysis, leak and spill control, containment and reuse, plus oil separation.

BAT guidelines call for increased limitations of the above parameters by installation of pond water dilution of sulfuric acid for the phosphate segment, and by installation of one of the following for the nitrogen segment: ammonia steam stripping followed by either high-flow ammonia air stripping or biological nitrification-denitrification, continuous ion exchange followed by denitrification, or advanced urea hydrolysis followed by high-flow ammonia air stripping.

NSPS standards call for the following process improvements for the nitrogen segment (phosphate segment is the same as BAT):

- Integration of ammonia process condensate steam stripping column into condensate boiler feed water systems of ammonia plant.

- Use of centrifugal rather than reciprocating compressors.

- Segregation of contaminated water collection systems so that common waste streams can be treated more efficiently and cheaply.

- Locate cooling towers upwind to minimize chance of absorbing ammonia in tower water.

- Design low velocity airflow prill tower for urea and ammonium nitrate to minimize dust loss.

- Design lower pressure steam levels in order to make process condensate and recovery easier and cheaper.

- Install air-cooled condensers and exchangers to minimize cooling water circulation and blowdown.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	$110.7
Incremental BPT O&M	$ 54.9

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. The principal reason for differences between these cost estimates and the newer data are increased unit cost estimates for BPT in ammonia and phosphate fertilizer plants in the G&P analysis.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-15-2.
Basic Fertilizer Chemicals
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (MT/Yr)	54,690.	73,600.	82,060.

Annual Growth Rate Over the Period 1976-1985 = 5.04%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985

Note: Residual data not available at time of Report issue.

1971 Controls:

Legislated Controls:

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	90.16	(BPT)	108.10	(BAT)	148.91
Pretreatment	0.00		0.00		0.00
New Plants	22.28		64.93		93.89
Municipal Investment Recovery	0.0		0.0		0.0
Totals	112.44		173.02		242.80

Table 4-15-2. (Continued)
Basic Fertilizer Chemicals
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	14.78	37.53	39.85	257.84[2]
O&M[3]				
On-site Treatment	3.98	9.79	33.00	114.03
Pretreatment	0.0	0.0	0.0	0.0
Totals	3.98	9.79	33.00	114.03
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	18.77	47.32	72.85	371.87

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Fertilizers industry includes production of ammonia, ammonium nitrates urea, and phosphate fertilizers.

ORGANIC CHEMICALS INDUSTRY

Production Characteristics and Capacities. Approximately 450 companies operating over 650 establishments are engaged in producing organic chemicals; however, the four largest producers account for a minimum of 36 percent, and the hundred largest for more than 92 percent of the total shipments. Much of the industry's production is accounted for not only by the large chemical companies, but also by the major petroleum refineries. At the other end of the spectrum are many small companies operating small plants. There are about 27 plants employing more than 1,000, and about 220 plants with less than 10 employees.

The organic chemicals industry includes a vast number of products and processes. The effluent limitations guidelines for Phases I and II of the industry cover only part of the organic chemicals industry. Primary petrochemical processing, (i.e., chemicals produced at petroleum refineries), plastics, fibers, agricultural chemicals, pesticides, detergents, paints, and pharmaceuticals are not included.

Synthetic organic chemicals are derivative products of naturally occurring raw materials (petroleum, natural gas, and coal) which have undergone at least one chemical conversion. The organic chemicals industry was initially dependent upon coal as its sole source of raw materials. However, during the last two decades it has moved so rapidly from coal to petroleum-based feedstocks that the term "petrochemicals" has come into common use.

The basic raw materials are usually obtained by physical separation processes in petroleum refineries. The raw materials are then chemically-converted to a primary group of reactive precursors; these precursors are then used in a multitude of specific chemical conversions to produce both intermediate and final products.

Processing of organic chemicals usually involves four stages: feed preparation - the vaporization, heating, compressing, and chemical or physical purification of raw materials; reaction - the reaction of the raw materials, usually in the presence of a catalyst; product separation - the condensation, distillation, absorption, etc., to obtain the desired product; product purification - distillation, extraction, crystallization, etc., to remove impurities. Processing methods may be carried out either in continuous operations or in individual batches. Facilities using the continuous processing method manufacture products at much greater volumes and at lower unit costs than those using the batch methods.

The effluent limitations guidelines promulgated to date by EPA (for Phase I) apply only to those products of the organics chemicals industry produced in continuous processing operations. These operations have been divided into seven subcategories, based first upon the degree of process water used, and second upon the raw waste loads generated; Table 4-16-1 lists the seven subcategories and the products and processes included.

Table 4-16-1.
Organic Chemicals Manufacturing Industry Products and Related Processes

Subcategory A Non Aqueous Processes

Products	Process Descriptions
BTX Aromatics	Hydrotreatment of pyrolysis gasoline
BTX Aromatics	Solvent extraction from reformate
Cyclohexane	Hydrogenation of benzene
Vinyl Chloride	Addition of hydrochloric acid to acetylene

Subcategory B Process with Process Water Contact as Steam Diluent or Absorbent

B1 Products	B1 Process Descriptions
Acetone	Dehydrogenation of isopropanol
Butadiene	Co-product of ethylene
Ethyl benzene	Alkylation of benzene with ethylene
Ethylene and Propylene	Pyrolysis of naphtha or liquid petroleum gas
Ethylene dichloride	Direct chlorination of ethylene
Ethylene oxide	Catalytic oxidation of ethylene
Formaldehyde	Oxidation of methanol
Methanol	Steam reforming of natural gas
Methyl amines	Addition of ammonia to methane
Vinyl acetate	Synthesis of ethylene and acetic acid
Vinyl chlorine	Cracking of ethylene dichloride

B2 Products	B2 Process Descriptions
Acetaldehyde	Dehydrogenation of ethanol
Acetylene	Partial oxidation of methane
Butadiene	Dehydrogenation of n-butane
Butadiene	Oxidative-dehydrogenation of n-butane
Styrene	Dehydrogenation of ethylbenzene

Table 4-16-1. (Continued)
Organic Chemicals Manufacturing Industry Products and Related Processes

Subcategory C	Aqueous Liquid Phase Reaction Systems
C1 Products	**C1 Process Descriptions**
Acetic acid	Oxidation of acetaldehyde
Acrylic acid	Synthesis with carbon monoxide and acetylene
Coal tar	Distillation of coal tar
Ethylene glycol	Hydrogenation of ethylene oxide
Terephthalic acid	Catalytic oxidation of p-xylene
Terephtahalic acid	Purification of crude terephthalic acid
C2 Products	**C2 Process Descriptions**
Acetaldehyde	Oxidation of ethylene with oxygen
Caprolactam	Oxidation of cyclohexane
Coal Tar	Pitch forming
Oxo Chemicals	Carbonylation and condensation
Phenol and Acetone	Cumene oxidation and cleavage
C3 Products	**C2 Process Descriptions**
Acetaldehyde	Oxidation of ethylene with air
Aniline	Nitration and hydrogenation of benzene
Bisphenol A	Condensation of phenol and acetone
Dimethyl terephthalate	Esterification of terephthalic acid
C4 Products	**C4 Process Descriptions**
Acrylates	Esterification of acrylic acid
p-cresol	Sulfunation of toluene
Methyl methacrylate	Acetone cyanohydrin process
Terephthalic acid	Nitric acid process
Tetraethyl lead	Addition of ethyl chloride to lead amalgum

Source: EPA Development Document, April 1973, pp. 28-29.

Waste Sources and Pollutants. Water is used in many production processes as a reaction vehicle, and also as a vehicle to separate or to purify the final products by scrubbing, steam stripping, or absorption. In addition, a considerable amount of water is used for heating (steam) and cooling, and for washing reaction and storage vessels, etc.

The effluent limitations guidelines for the organic chemicals industry cover the following pollutants: BOD_5, COD, total suspended solids, phenols, and pH. The limitation placed upon pH in all cases in between 6.0 and 9.0. It should be noted that process wastewaters subject to limitations include all process waters exclusive of auxilary sources, such as boiler and cooling water blowdown, water treatment back wash, laboratories, and other similar sources.

Control Technology and Costs. Technologies employed in the organic chemicals industry for the control of wastewater pollutants include in-process modifications, pollution control equipment, and end-of-pipe wastewater treatment. From a pollution-control standpoint, the most significant change that can be made in process chemistry is from a "wet" process to a "dry" process; that is, the substitution of some other solvent for water in which to carry out the reaction or to purify the product. Other in-process technologies observed or recommended for the organic chemicals industry include the substitution of surface heat exchangers for contact cooling water, substitution of vacuum pump steam jet ejectors, recycle of scrubber water, and regeneration of contact process steam from contaminated condensate.

Biological treatment systems are the most common end-of-pipe technologies used in the organic chemicals industry today. These systems include activated sludge, trickling filters, aerated lagoons, and anaerobic lagoons. Other systems used include stripping towers, deep-well disposal, physical treatment, activated carbon, and incineration. Where phenols are present in wastewaters, they may be removed by solvent extraction, carbon absorption, caustic precipitation, or steam stripping; cyanide may be removed by oxidation. Five of 34 plants surveyed discharged their effluent to a municipal treatment system; three had no current treatment systems.

In-process controls commensurate with BPT include segregation of waste streams, the substitution of nonaqueous media in which to carry out the reactions or to purify the products, recycling or reuse of process water, and the recovery of products and byproducts from the wastewaters by solvent extraction, absorption, or distillation. End-of-pipe treatment commensurate with BPT is based on the use of biological systems as mentioned above. These systems include additional treatment operations such as equalization, neutralization, primary clarification with oil removal, nutrient addition, and effluent polishing steps, such as coagulation, sedimentation, and filtration. Phenol removal is also required in some cases.

Technology commensurate with BAT includes the addition of activated carbon to the BPT biological systems to achieve substantial reductions of dissolved organic compounds. In-process controls applicable to BAT include:

- Substitution of non-contact heat exchangers for direct contact water cooling
- Use nonaqueous quench media
- Recycle process water
- Reuse process water as a make-up to evaporative cooling towers
- Use process water to produce low pressure steam by non-contact heat exchange
- Recover spent acids or caustic solution for reuse
- Recover and reuse spent catalysts
- Use nonaqueous solvents for extraction products.

End-of-pipe technology for NSPS is defined as biological treatment with suspended solids removal via clarification, sedimentation, sand, or dual-media filtration. In addition, exemplary in-process controls, as previously enumerated, are also assumed to be applicable, particularly where biotoxic pollutants must be controlled.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

	Total	Phase I	Phase II
Incremental BPT Investment	$941.2	684.0	257.3
Incremental BPT O&M	$ 75.5	55.1	20.5

Estimates form the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Principal reasons for differences between these cost estimates and the newer data are industry definition expansion, different estimates of "capital-in-place", different model plant sizes, and different hydraulic load data.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-16-2.
Organic Chemicals
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity:			
Phase I (1,000 Liters/Day)	4,515,900.	6,736,900.	7,336,900.
Phase II (kkg/Day)	37,140.	55,406.	60,335

Annual Growth Rate Over the Period 1976-1985:
Phase I = 6.65%
Phase II = 6.65%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	48.16	65.22	68.77
BOD5	274.85	370.77	393.49
COD	798.04	1,079.50	1,143.76
Dissolved Solids	3,756.08	5,251.61	5,616.55
Oils and Greases	11.05	14.79	15.68
Acids	0	0	0
Bases	18.46	25.81	27.44
Nutrients	25.78	36.37	66.12
Legislated Controls:			
TSS	17.39	4.98	2.94
BOD5	79.21	7.39	4.41
COD	628.97	322.76	185.60
Dissolved Solids	3,767.03	5,237.20	5,591.88
Oils and Greases	10.43	12.99	13.57
Acids	0	0	0
Bases	16.24	21.69	22.97
Nutrients	25.84	36.19	61.29

CONTROL COSTS (Million 1975 $) Phase I	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	995.55	(BPT)	1,465.44	(BAT)	1,954.53
Pretreatment	6.00		0.00		0.00
New Plants	337.61		1,685.03		2,175.05
Municipal Investment Recovery	26.83		229.06		336.46
Totals	1,365.98		3,379.53		4,466.03

Table 4-16-2. (Continued)
Organic Chemicals
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Phase I (Continued)				
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	176.06	590.11	631.47	4,006.74[2]
O&M[3]				
On-site Treatment	682.18	1,063.43	1,364.76	9,586.90
Pretreatment	2.66	4.13	4.49	35.71
Totals	684.84	1,067.56	1,369.25	9,622.60
Municipal Charges				
Investment Recovery	12.11	42.97	43.88	336.46
User Charges[4]	21.14	42.36	44.65	493.40
Totals	33.25	85.33	88.52	829.86
Grand Totals	894.15	1,742.99	2,089.24	14,459.20

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Phase I Organic Chemicals industry includes subcategories A, B-1, B-2, C-1, C-2, C-3, and C-4 as defined in Table 4-16-1.

Table 4-16-2. (Continued)
Organic Chemicals
Industry Data Summary

CONTROL COSTS (Million 1975 $)			AGGREGATED OVER		
Phase II					
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	71.12	(BPT)	511.83	(BAT)	553.58
Pretreatment	13.87		0.00		0.00
New Plants	33.35		167.16		215.79
Municipal Investment Recovery	15.77		134.64		197.76
Totals	134.10		813.63		967.14

		COST IN YEAR		
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	15.55	104.82	108.91	595.64[2]
O&M[3]				
On-site Treatment	24.45	41.58	117.89	496.50
Pretreatment	5.38	8.81	9.54	75.62
Totals	29.83	50.39	127.43	572.12
Municipal Charges				
Investment Recovery	7.12	25.26	25.79	197.76
User Charges[4]	12.43	24.90	26.24	290.02
Totals	19.54	50.16	52.03	487.78
Grand Totals	64.92	205.36	288.37	1,655.54

Table 4-16-2. (Continued)
Organic Chemicals
Industry Data Summary

Phase II (Continued)

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Phase II Organic Chemicals industry includes subcategories B-3, C-3, C-5, C-6 and D-4 as defined in Table 4-16-1.

PHOSPHATE MANUFACTURING INDUSTRY

Production Characteristics and Capacities. Establishments included in the phosphate manufacturing industry as defined by the effluent limitations guidelines are manufacturers of the following chemicals:

- Phosphorus
- Ferrophosphorus
- Phosphoric acid (dry process)
- Phosphorus pentoxide
- Phosphorus pentasulfide
- Phosphorus trichloride
- Phosphorus oxychloride
- Sodium tripolyphosphate
- Calcium phosphates (food grade)
- Calcium phosphates (animal feed grade).

This industry is almost entirely based on the production of elemental phosphorus from mined phosphate rock. Elemental phosphorus and ferrophosphorus (a byproduct) are manufactured by the reduction of phosphate rock by coke in very large electric furnaces, using silica as a flux. Because elemental phosphorus is relatively low in weight compared to phosphate rock and to phosphoric acid, the elemental phosphorus is produced near the mining site and shipped to locations near the final markets for further processing.

Over 87 percent of the elemental phosphorus is used to manufacture high-grade phosphoric acid by the furnace or dry process. This process involves burning of liquid phosphorus in air, the subsequent quenching and hydrolysis of the phosphorus pentoxide vapor, and the collection of the phosphoric acid mists.

The manufacture of the anhydrous phosphorus chemicals - phosphorus pentoxide (P_2O_5), phosphorus pentasulfide (P_2S_5), and phosphorus trichloride (PCl_3) - is essentially the direct union of phosphorus with the corresponding element. Phosphorus oxychloride ($POCl_3$) is manufactured from PCl_3 and air or from PCl_3, P_2O_5, and chlorine.

Sodium tripolyphosphate is manufactured in the neutralization of phosphoric acid with caustic soda and soda ash in mix tanks. The resulting mixture of mono-and di-sodium phosphates is dried and the crystals calcined to produce the tripolyphosphate.

The calcium phosphates are similarily made by the neutralization of phosphoric acid with lime. The amount and type of lime used and the amount of water needed in the process determine whether anhydrous monocalcium phosphate monohydrate, dicalcium phosphate dihydrate, or tricalcium phosphate is the final product. Animal feed grade dicalcium phosphate is produced by the same process as the other calcium phosphates except that, because less purity in the final product is necessary, wet process phosphoric acid is normally used and the reaction may be conducted without excess water.

For the most part, the products included in the phosphate manufacturing industry are produced by divisions of large chemical or petroleum companies. The derivatives of phosphorus are generally manufactured by the same companies that produce elemental phosphorus. Furthermore, a large proportion of the products are used internally by the producing company for the production of other products and, hence, are not sold on the open market.

The biggest factors determining the future of the industry are government regulation and technological innovation. The declining production of phosphorus, for example, is the result of government bans on phosphate detergents. In addition, the TVA plant is expected to shut down in 1976, as a shift to production of wet phosphoric acid is accomplished.

Waste Sources and Pollutants. Water is primarily used in the phosphate manufacturing industry for eight principal purposes: non-contact cooling water, process and product water, transport water, contact cooling or heating water, atmospheric seal water, scrubber water, auxiliary process water, and miscellaneous uses. Very large quantities of non-contact cooling water are used for cooling the electric furnaces used in phosphorus production. Contact cooling water is used to quench the slag from the phosphorous furnaces. Process or product water contacts and generally becomes part of the product, such as the hydrolysis and dilution water used in phosphoric acid manufacture and the water used as a reaction medium in food-grade dicalcium phosphate manufacture. Because some of the materials in this industry spontaneously ignite on contact with air, the air is kept out of reaction vessels with a water seal, and liquid phosphorus is protected by storage under a water blanket; these seal waters are considered process waters. Auxiliary process water includes those used in such auxiliary operations as ion exchange regeneration, equipment washing, and spill and leak washdown.

The following pollutant parameters have been designated for the industry's process wastewaters: total suspended solids, phosphate and elemental phosphorus, sulfates and sulfites, fluoride, chloride, dissolved solids, arsenic, cadmium, vanadium, radioactivity, temperature (heat), and pH. The primary parameters, i.e., those which need to be used to set effluent standards, are total suspended nonfilterable solids, total phosphorus, fluoride, arsenic, and pH. The remaining pollutants are either adequately treated when the primary parameters are treated, or are present only in waste streams for which a zero discharge standard has been set.

The effluent limitations guideline for most of the phosphate manufacturing industry is discharge of process wastewater pollutants to navigable waters. Process water is defined as any water that comes into direct contact with any raw material, intermediate product, byproduct, or gas or liquid that has accumulated such constituents.

The only exceptions to these standards are the BPT guidelines for phosphorus and ferrophosphorus, phosphorus trichloride, phosphorus oxychloride, and food-grade calcium phosphates.

Control Technology and Costs. Traditional sanitary engineering practices that treat effluents containing organic material in order to reduce biological oxygen demand are inapplicable to the phosphate manufacturing industry where such pollutant constituents are not significant. Hence, control and treatment of wastes are of the chemical and chemical engineering variety. These include neutralization, precipitation, ionic reactions, filtration, centrifugation, ion exchange, demineralization, evaporation and drying. In-process abatement measures include segregation of waste streams, recycling scrubber water, dry dust collection, containment of leaks and spills, and minimization of the quanitity of wash water. Table 4-17-1, lists the major treatment alternatives that have been identified for manufacturers in the phosphate manufacturing industry. Many of the manufacturing establishments currently have no treatment installed, while others have already achieved zero discharge.

Table 4-17-1.
Phosphate Manufacturing Industry Effluent Treatment Alternatives

Subcategory	**Chemical**	**Alternative**	**Description**
Phosphorus consuming	$P_4(Fe_2P)$	A	Existing control complete recycle of phossy water. Evaporation of some other process water. Lime treatment and sedimentation of remaining process water prior to discharge.
		B	Piping, pumping, and controls for 100% recycle of process wastewaters.
Phosphorus consuming	H_3PO_4	A	No treatment. (Only wastewaters originate from leaks, spills, etc.)
		B	Tighten housekeeping and maintenance. Dike and dam around pumps, valves, tanks, etc. Provide sumps and sump pumps. Treat with lime and landfill the sludge.
	P_2O_5	A	No treatment.
		B	Lime treatment, settling tank, recycle of tank overflow back to process, and landfill sludge.
	P_2S_5	A	No treatment.
		B	Recycle scrubber water.
		C	Lime treatment, settling tank, recycle tank overflow back to process, landfill sludge, + B.
	PCl_3	A	No treatment.
		B	Recycle scrubber water.
		C	Lime treatment, settling tank and landfill sludge, + B.
		D	Evaporation, + B + C.
	$POCl_3$	A	No treatment.
		B	Recycle scrubber water.
		C	Lime treatment, settling tank, and landfill sludge + B.
		D	Evaporation + B + C.
Phosphate producing	$Na_5P_3O_{10}$	A	Dry dust collection already in existance at exemplary plant. May be economically justified on the basis of product recovery.
	$CaHPO_4$	A	In-process controls for phosphate and lime dusts and for phosphoric acid mists, including dry dust collection and scrubber water recycle to process.
		B	Lime treatment, settling pond, recycle of clarified water to acid scrubbers, and landfill sludge, + A.
	$CaHPO_4$ Feed grade	A	Replace wet scrubbers with baghouses.
		B	Lime treatment, filtration of slurry, recycle of filtrate, and landfill of filter cake, + A.

Source: EPA Development Document, January 1974.

The technology recommended to achieve zero discharge of wastewaters in the phosphate manufacturing industry consists of recycling atmospheric seal ("phossy") waters, scrubber liquors, and other process waters following lime treatment and sedimentation or alternative methods of reducing water flow, such as the use of dilute caustic or lime slurry instead of pure water in the process; use of dry dust collectors, and the return of process waste streams and blowdown streams to the process.

Zero discharge of arsenic-rich still residues from the manufacture of phosphorus trichloride can be achieved through treatment with trichloroethylene.

For those industry subcategories where some discharge is allowed, the recommended treatment consists of waste-reducing steps such as those above, but with some discharge following lime treatment and sedimentation, sometimes with flocculation. Additional treatment to achieve zero discharge for these subcategories consists of total recycling of all process waters for phosphorous producer; control of PCl_3 vapors by installation of refrigerated condensers, minimization of wastewaters and treatment by lime neutralization followed by evaporation to dryness for manufacturers of phosphorus trichloride and phosphorus oxychloride; and the addition of vacuum filtration of treated wastewaters followed by total recycling for producers of food-grade calcium phosphates.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The phosphate G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	68.6
Incremental BPT O&M	15.5

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. The principal reason for the differences is that G&P scaled the costs associated with each model plant size because of industry and Department of Commerce comments concerning the low level of the estimates.

[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972," National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-17-2.
Phosphate Manufacturing
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (kkg/Day)	16,590.	26,567.	28,938.

Annual Growth Rate Over the Period 1976-1985 = 7.23%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985

Note: Residual data not available at time of Report issue.

1971 Controls:

Legislated Controls:

CONTROL COSTS (Million 1975 $)		AGGREGATED OVER			
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	33.21	(BPT)	34.13	(BAT)	49.76
Pretreatment	0.00		0.00		0.00
New Plants	1.83		42.88		50.57
Municipal Investment Recovery	0.0		0.0		0.0
Totals	35.05		77.01		100.33

Table 4-17-2. (Continued)
Phosphate Manufacturing
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	4.61	14.73	15.74	100.27[2]
O&M[3]				
On-site Treatment	4.41	8.33	11.18	72.26
Pretreatment	0.0	0.0	0.0	0.0
Totals	4.41	8.33	11.18	72.26
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	9.02	23.06	26.92	172.53

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Phosphate Manufacturing industry includes the production of elemental phosphorus from mined phosphate rock.

PLASTICS AND SYNTHETICS INDUSTRY

Production Characteristics and Capacities. The plastics and synthetics industry comprises 17 product subcategories. Current effluent limitations guidelines do not apply to four product subcategories, epoxies, melamine, urea, and phenolics, and the 13 remaining product subcategories are: polyvinyl chloride, ABS/SAN, polystyrene, polyvinyl acetate, low-density polyethylene, high-density polyethylene, polypropylene, acrylic, polyester, nylon 6 and nylon 66, cellophane, cellulose acetate, and rayon.

The main raw materials sources for the plastics and synthetics industry are petroleum and natural gas. In terms of volume, the rayon, cellophane, and cellulose acetate subcategories are the major producers. The plastics and synthetics industry is an intermediate type industry that takes the processed raw material or monomer and converts it into a resin or plastic material which is later converted into a plastic item by another segment of the industry.

Over 50 percent of synthetic resins are used for one of the following:

- Building and construction: paint, flooring, wall covering, siding, etc;
- Packaging: polyethylene films, rigid plastic containers and bottles, etc.; and
- Automotive: trim, steering wheels, grill, etc.

Manufacturing in the various subcategories involves a variety of chemical polymeterization processes in which the large synthetic molecules, or polymers, are formed. In the high pressure mass polymerization process, ethylene gas is mixed with air or oxygenated organic compounds as catalysts and with recycled ethylene. This mixture is then raised to a high temperature in a reciprocating compressor to produce the desired polymer; in this case, low density polythylene. Rayon, polyester, cellulose acetate and other fibers are produced by adding a spinning process after the polymerization is complete.

Exports amount to 6-8 percent of production and outstripped imports, which only amounted to 4-5 percent of consumption. Foreign competition is intense, but it has no significant effect on potential domestic revenue.

Waste Sources and Pollutants. In order to set effluent limitations guidelines, the dimension of wastewater characteristics was chosen as a basis for subcategorization. The four major subcategories are defined as:

- Major Subcategory I: Low waste load (< 10 kg/kkg), low attainable BOD_5 concentration (< 20 mg/l). Products affected: polyvinyl chloride, polyvinyl acetate, polystyrene, polyethylene, and polypropylene.

- Major Subcategory II: High waste load (> 10 kg/kkg), low attainable BOD_5 concentration (< 20 mg/l). Products affected: ABS/SAN, cellophane, and rayon.

- Major Subcategory III: High waste load (> 10 kg/kkg), medium attainable BOD_5 concentration (30-75 mg/l). Products affected: polyesters, nylon 66, nylon 6, and cellulose acetates.

- Major Subcategory IV: High waste load (> 10 kg/kkg), low treatability. Product affected: acrylics.

The main sources contributing to the total waste load come from spills, leaks, and accidents. Other sources include: washdown of process vessels, area housekeeping, utility blowdown, and laboratory wastes. Waste streams from cooling towers, steam-generating facilities, and water treatment facilities are generally combined with process wastewater and then are sent to the treatment plant.

In order to define waste characteristics, the following basic parameters were used to develop guidelines for meeting BPT, BAT, and NSPS: BOD_5, COD, TSS, zinc, pH, phenolic compounds, and total chromium.

Control Technology and Costs. Waste treatment methods in the plastics and synthetics industry include the following: biological treatment, single or double stage aeration, adsorption, granular-activated carbon systems, chemical precipitation, anaerobic process, air stripping, chemical oxidation, foam separation, algae systems, incineration, liquid extraction, ion exchange, reverse osmosis, freeze thaw, evaporation, electrodialysis, and in-plant controls.

BPT guidelines for existing point sources are based on the application of end-of-pipe technology, such as biological treatment for BOD reduction by activated sludge, aerated lagoons, trickling filters, aerobic-anaerobic lagoons, etc., with preliminary treatment typified by equalization, dampening of shock loadings, settling, and clarification. BPT also calls for chemical treatment for the removal of suspended solids, oils, and other elements, as well as pH control and subsequent treatment typified by clarification and polishing processes for additional BOD and suspended solids removal, and dephenolizing units for phenolic compound removal when needed. In-plant technology and other changes that may be helpful in meeting BPT include segregation of contact process wastewater from non-contact wastewaters, elimination of once-through barometric condensers, control of leaks, and good housekeeping practices.

BAT standards call for the segregation of contact process waters from non-contact wastewater, maximum wastewater recycle and reuse, elimination of once-through barometric condensers, control of leaks, good housekeeping practices and end-of-pipe technology, further removal of suspended solids and other elements typified by media filtration, chemical treatment, etc. Also included are further COD removal as typified by the application of adsorptive flocs, and incineration for the treatment of highly-concentrated, small volume wastes, as well as additional biological treatment for further BOD_5 removal when needed.

NSPS are based on BPT and call for the maximum possible reduction of process wastewater generation and the application of media filtration and chemical treatment for additional suspended solids, other element removal, and additional biological treatment for further BOD_5 removal as needed.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	$355.6
Incremental BPT O&M	$ 36.3

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Principal reasons for differences between these cost estimates and the newer data are basic industry definition expansion, changes in plant inventory estimates, different estimates of "capital-in-place", and varying discharges to municipal treatment systems.

[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-18-1.
Plastics and Synthetics
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (Million kg/Yr)	57.96	93.35	102.01

Annual Growth Rate Over the Period 1976-1985 = 8.19%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	193.83	264.80	281.91
BOD$_5$	417.96	585.34	625.88
COD	870.28	1,218.97	1,303.85
Dissolved Solids (Rayon only)	22.47	34.02	37.09
Legislated Controls:			
TSS	123.55	80.41	67.11
BOD$_5$	213.79	82.75	55.06
COD	516.10	294.80	228.09
Dissolved Solids (Rayon only)	5.91	.25	.16

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	464.63	(BPT)	228.83	(BAT)	474.03
Pretreatment	38.80		0.00		0.00
New Plants	167.12		870.15		1,084.39
Municipal Investment Recovery	0.04		0.36		0.53
Totals	670.59		1,099.34		1,558.95

Table 4-18-1. (Continued)
Plastics and Synthetics
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	88.16	232.65	249.67	1,729.41[2]
O&M[3]				
On-site Treatment	75.51	144.60	158.06	1,211.52
Pretreatment	2.08	3.98	4.29	33.21
Totals	77.59	148.58	162.34	1,244.72
Municipal Charges				
Investment Recovery	0.02	0.07	0.07	0.53
User Charges[4]	0.03	0.07	0.07	0.80
Totals	0.05	0.14	0.14	1.32
Grand Totals	165.80	381.36	412.16	2,975.45

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Plastics and Synthetics industry includes production of cellophane, rayon, polyester, and nylon 6.

PETROLEUM REFINING INDUSTRY

Production Characteristics and Capacities. The petroleum refining industry comprises about 130 firms operating 247 refineries in 39 states. Firms in the petroleum refining industry can be classified according to size, range of products, extent of integration, and the number and size of refineries owned. All refineries are necessarily multi-product, and all perform the entire process of converting crude oil into salable products. As of 1974, the 17 largest firms, operating 110 of the 247 refineries, accounted for 80 percent of the industry's capacity.

The petroleum refining industry produces hundreds of distinguishably different products, which can be grouped into four broad product classes: gasoline, intermediates, residual, and oil and all others. Gasoline accounts for about 45 percent of industry output; intermediates comprise about 33 percent, including military and commercial jet fuel, kerosene, space heating oil, and diesel fuel; residual oil amounts to about 8 percent of domestic petroleum production; and other all products include asphalt, lubricants, liquefied petroleum gas (mostly propane), naphthas and solvents, coke, petrochemicals, and petrochemical feedstocks. Crude oil is the most important raw material used by the industry; natural gasoline, a liquid product of the natural gas industry, furnishes about 5 percent of refinery intakes. There are no other significant raw materials.

Small refineries are designed to process low-sulfur crude oil into the naturally occurring volumes of gasoline, intermediates, and residual products. Such refineries require only a crude oil distillation unit, a catalytic reformer with feed pretreater, two or three additional distillation columns, and treating units. Because asphalt, one of the residual products, is costly to transport, a large percentage of the nation's asphalt is produced in small refineries. Over a third of the plants with capacities below 10,000 barrels per day produce asphalt as a principal product.

On the other hand, large refineries produce a full range of fuel products plus lubricants, industrial solvents, liquified petroleum gas, and a few common chemicals; these refineries have more than a score of process units to produce these diversified products.

Although a typical oil refinery is technically complex, the process is conceptually simple. Crude oils, which are liquid mixtures of many carbon-containing compounds, are first separated into several groups of varying molecular size known as cuts. The chemical composition of some of these cuts is then altered by changing the average molecular size. Some cuts are further processed to alter the shape or structure of the molecules. Most of the original cuts are "treated" to make the impurities innocuous or to remove them completely, particularly sulfur. Treated cuts are then blended to produce finished products, to which various substances, known as additives, may be added to impart certain desireable properties.

Refining operations may be divided into 12 general categories or groups of refining operations:

- Storage and transportation
- Crude processes
- Coking processes
- Cracking and thermal processes
- Hydrocarbon processing
- Petrochemical operations
- Lube manufacturing processes
- Treating and finishing
- Asphalt production
- Auxiliary activities.

Refineries, which may incorporate some or all of these operations, are classified according to the specific operations included. Based upon an analysis of refinery raw waste loads, EPA has divided the industry into five subcategories:

Topping. Topping plants are refineries whose processing is largely confined to converting oil into raw products by simple atmospheric distillation. The topping subcategory includes all refineries that combine all processes except cracking and coking.

Cracking. The term cracking applies to a group of processes in which heavy molecular weight or fractions are broken down into lower weight fractions. Refineries in this subcategory are those that have topping and cracking operations.

Petrochemical. Plants in this subcategory have topping, cracking, and petrochemical operations.

Lube. This subcategory includes refineries with topping, cracking, and lube oil manufacturing processes.

Integrated. Integrated refineries are those with topping, cracking, lube oil manufacturing processes, and petrochemical operations.

Current industry capacity is approximately 14 million barrels per day. Very few new refineries have been built in the last 5 years, and industry growth has occurred primarily through the expansion of existing facilities. This situation is caused in part by the difficulty in securing approval for new refinery sites. The intensity of the energy shortage in 1974 resulted in the largest absolute capacity increase since 1967 and the largest percentage increase in at least a decade. This increase was 6.2 percent, compared with 2.3-4.3 percent for the preceding 3 years.

Waste Sources and Pollutants. Wastewater pollutants are generated in the various refining processes as high temperature water, suspended solids, total organic carbon, and salts separated from the crude oil. Acids, caustics, catalysts, and various solvents that are brought into contact with the oil are collected, washed out, or allowed to leak into the waste stream. Pollutants also enter the waste stream from washing tanks, equipment, catalysts, etc.; from cooling water blowdown; and from leaks and spillage. Additional flows and waste loads are created by storm water runoff from the refineries' grounds and from the disposal of ballast water.

The following parameters are covered under the effluent limitations guidelines: BOD_5, total suspended solids, COD, oil and grease, phenolic compounds, ammonia (as N), sulfide, total chromium, hexaualent chromium, and pH.

Each different process in the oil industry is a series of unit operations that cause chemical and or physical synthesis of the desired products. Each unit operation may have drastically different water usages associated with it; this in turn implies that the types and quantities of wastewater generated by each plant's total production mix are unique.

Control Technology and Costs. Wastewater treatment processes currently used in the petroleum refining industry include equalization and storm diversion; initial oil and solids removal (API separators or baffle plate separators); further oil and solids removal (clarifiers, dissolved air flotation, or filters); carbonaceous waste removal (activated sludge, aerated lagoons, oxidation ponds, trickling filter, activated carbon, or combinations of these); and filters (sand or multi-media) following biological treatment methods.

BPT guidelines are based upon both in-plant and end-of-pipe control practices widely used within the industry. These include the above listed end-of-pipe technologies plus:

- Installation of sour water strippers to reduce the sulfide and ammonia concentrations entering the treatment plant.
- Elimination of once-through barometeric condenser water by using surface condensers or recycle systems with oily water cooling towers.
- Segregation of sewers, so that unpolluted storm runoff and once-through cooling waters are not treated normally with the process and other polluted waters.
- Elimination of polluted once-through cooling water by monitoring and repair of surface condensers or by use of wet and dry recycle systems.
- Granular media filtration or polishing ponds prior to discharge.

BAT guidelines call for further reductions of water flow in-plant, and the addition of a physical-chemical treatment step (activated carbon) in the end-of-pipe treatment system. BAT in-plant technology is based on control practices now in use by some plants in the industry and include:

- Use of air cooling equipment.
- Reusing: sour water stripper bottoms in crude desalter; once-through cooling water as make-up to the water treatment plant; boiler condensate as boiler feedwater; overhead accumulator water in desalters; and heated water from the vacuum overhead condensers to heat the crude.
- Recycling: water from coking operations, waste acids from alkylation units; and overhead water in water washes.
- Use of wastewater treatment plant effluent as cooling water, scrubbing water, and influent to the water treatment plant.
- Use of closed compressor and pump cooling water system.

- Use of rain water runoff as cooling tower make-up or water treatment plant feed.

NSPS are based upon the application of BPT practices to the wastewater flows used as the basis for BAT.

The most recent anlysis of costs for this sector was provided to the Agency by Sobotka & Co., Inc., (S&C)[1]. This analysis was conducted in somewhat greater depth than, and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure, and is considered to be more precise. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The S&C estimates are as follows (in million 1975 dollars):

	BPT	BAT
Incremental Investment	$1,610	$476
Incremental O&M	$ 180	$ 46

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Principal reasons for differences between these cost estimates and the newer data are different estimates of "capital-in-place", differences in attribution of O&M to federal laws, and differences in cost estimates for sludge handling. It is interesting to note that the forecasts of investment expenditures over the period 1976-1985 are in extremely close agreement for both studies, with S&C forecasting 1,770 million dollars and SEAS listing 1,713. S&C assumes elimination of the "once-through" cooling water to be identified with BPT systems, whereas SEAS placed this to be BAT treatment. Of the total S&C incremental investment figure for BPT, 43 percent is related to end-of-pipe treatment processes or auxiliary and handling equipment. This figure represents an estimate 27 percent higher than the SEAS corresponding projection. Much of the difference in these two figures can be attributed to engineering assumptions about equipment necessary for auxiliary and sludge handling, which accounts for over 45 percent of these costs. S&C also estimates $379 million for BPT related expenditures on in-plant measures. SEAS includes associated land costs, unlike S&C. The methodology for extrapolating costs differed markedly between the two studies. S&C made its primary distinction between large and small plants (<10,000 barrels/day). For large plants, data was available such that cost calculations could be made for 121 refineries. These were then extrapolated over the entire category. For small plants, 11 refineries, were sampled, and the results similarly extrapolated. SEAS calculations are based upon model plants in several categories. Three model plant sizes were assumed for topping; three for catalytic cracking; three for petrochemicals, BPT treatment; five for BAT treatment; lube oils lists three model plant sizes for BPT, with six for BAT; and integrated having three classes for BPT; five for BAT.

Another important factor in the cost estimates is the assumed growth pattern. Although S&C and SEAS differ very little in total growth for 1972-1983, the distribution of the growth is graphically different. S&C assumes that 64 percent of the growth occurs between 1973 and 1977 (3,195,000 barrels/day), while SEAS assumes only 23.3 percent of overall growth (1,179,800 barrels/day) to occur during the initial five-year period.

S&C also calculates costs for "grass roots" refineries and expansions on a different basis. The expansions after 1977 must make substantially higher investments, so the total expansions investment figure is somewhat weighted toward this latter period. The distribution of the growth in size categories also differed markedly between the two studies with S&C assuming expansion in the large plant sizes, with SEAS making no distinctions between types of expansion and spreads the expansion over the model plant sizes.

[1] "Economic Impact of EPA's Regulations on the Petroleum Refining Industry", Sobotka & Co., Inc., April, 1976.

Table 4-19-1.
Petroleum Refining
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (1,000 Bbl/Day)	15,776.	20,228.	21,651.

Annual Growth Rate Over the Period 1976-1985 = 3.99%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	10.66	13.66	14.59
BOD_5	19.62	25.14	26.84
COD	88.78	113.73	121.44
Oils and Greases	3.01	3.86	4.12
Legislated Controls:			
TSS	9.31	5.95	4.53
BOD_5	15.81	7.72	4.51
COD	88.15	44.39	23.83
Oils and Greases	3.14	1.60	.85

CONTROL COSTS (Million 1975 $)			AGGREGATED OVER		
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	447.34	(BPT)	913.11	(BAT)	1,136.89
Pretreatment	1.55		0.00		0.00
New Plants	24.47		421.72		532.01
Municipal Investment Recovery	3.91		30.36		44.68
Totals	477.27		1,365.19		1,713.57

Table 4-19-1. (Continued)
Petroleum Refining
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	62.23	237.73	252.06	1,481.60[2]
O&M[3]				
On-site Treatment	67.64	99.17	168.00	961.79
Pretreatment	0.41	0.36	0.32	3.72
Totals	68.05	99.53	168.32	965.51
Municipal Charges				
Investment Recovery	1.73	5.64	5.74	44.68
User Charges[4]	2.90	4.78	4.93	59.77
Totals	4.62	10.42	10.67	104.45
Grand Totals	134.91	347.68	431.05	2,551.55

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Petroleum industry includes topping, cracking, petrochemical, lube oil, and integrated refining processes.

RUBBER PROCESSING INDUSTRY

Production Characteristics and Capacities. The Phase I categories of the rubber processing industry covered by the effluent limitations guidelines are the tire and inner tube industry and the synthetic rubber industry.

The manufacture of tires and inner tubes employs completely different processing techniques than does the production of synthetic rubber. The typical tire manufacturing process includes the following:

- Preparation or compounding of the raw materials
- Transformation of these compounded materials into five tire components--tire bead coating, tire treads, tire sidewall, inner liner stock, and coated cord fabric
- Building, molding, and curing the final product.

The raw materials used include a variety of synthetic and natural rubbers; three categories of compounding materials: filler, extenders, and reinforcers (carbon black and oil are two common examples); and other chemicals that are used as antioxidants, pigments, or curing and accelerator agents. Compounding is usually carried out in a batch-type, internal mixing device called a Banbury mixer. After mixing, the compound is sheeted out in a roller mill, extruded into sheets, or pelletized. The sheeted material is tacky and must be coated with a soapstone solution to prevent the materials from sticking together during storage. The compounded rubber stock is transformed into one of the tire components by molding, extruding, calendering, and a variety of other operations. The tire is built up as a cylinder on a collapsible, round rotating drum by applying the inner layer, then by adding layers of cord, beads, belt, and tread. Finally the "green" tire is molded and cured in an automatic press, and the excess rubber is ground off. Inner tubes are produced using the same basic processing steps.

The synthetic rubber industry is responsible for the production of vulcanizable elastomers by polymerization or co-polymerization. Table 4-20-1 identifies the various synthetic rubbers, and lists their principal production processes and end uses.

Table 4-20-1.
Rubber Processing Industry
Synthetic Production Statistics

Families of Synthetic Rubbers Included in SIC 2822, Polymerization Processes, and Annual U.S. Production (1972)

Principal Synthetic Rubber	Annual U.S. Production (1,000 MT/yr)	Polymerization Process	Principal End-use	Other Family Members
Tire Rubbers				
Styrene-Butadiene rubbers (SBR)	1,678 139	Emulsion Solution	General tire use Tire treads	
Polybutadiene rubbers (PBR)	368	Solution	Tire treads	
Polyisoprene rubbers	139	Solution	Tire treads	
Polyisobutylene-isoprene rubbers (Butyl)	163	Solution	Inner tubes	
Ethylene-Propylene Co-polymer rubbers (EPR)	169 169	Solution Solution	General tire use, non-tire goods	EPDM
Acrylonitrile-Butadiene rubbers (Nitrile)[1]	159	Emulsion	Hose, seals, gaskets, O-rings	
Polychloroprene rubber (Neoprene)[1]	177	Emulsion	Non-tire use, general tire use	Neoprene, nitile-chloroprene rubber, styrene-chloroprene rubber
Tire Rubber Sub-Total:	2,992			
Specialty Rubbers				
Butadiene rubbers	64	Emulsion	Adhesives, dipped goods, paints	Pyridine-butadiene rubber
Epichlorohydrin rubber	9	Solution	Seals, gaskets and O-rings	Cyclo rubber
Acrylic rubbers	2	Emulsion	Seals, hosing, tubing	Acrylate type rubber, Acrylate-butadiene rubber
Polyisobutylene rubbers	4	Solution	Caulking, adhesives, plastics	
Silicone rubbers[2]	10	Condensation	Seals, gaskets, electrical tape	
Polyurethane rubbers	14	Condensation	Solid tires, rollers, foams fibers	Adiprene, estane, isocynate type rubber

[1] Although nitrile and neoprene-type rubbers are not normally termed tire rubbers, they are relatively large production volume rubbers and, for convenience, can be included with the major tire rubbers.

[2] Silicone, polyurethane and fluorocarbon derivative rubbers are considered part of the Plastics and Synthetics Industry and are not covered by this document.

Table 4-20-1. (Continued)
Rubber Processing Industry
Synthetic Production Statistics

Principal Synthetic Rubber	Annual U.S. Production (1,000 MT/yr)	Polymerization Process	Principal End-use	Other Family Members
Chlorosulfonated Polyethylenes[3]	15	Post-polymerization chlorination	Wire and cable, shoes, linings, paints	Chlorinated rubber, Hypalon
Polysulfide rubbers[4]	10	Condensation	Sealing, glazing, hose	Thiol
Specialty Rubber Sub-Total	129			
Synthetic Rubber Total	3,121			

[1] Although nitrile and neoprene-type rubbers are not normally termed tire rubbers, they are relatively large production volume rubbers and, for convenience, can be included with the major tire rubbers.

[2] Silicone, polyurethane and fluorocarbon derivative rubbers are considered part of the Plastics and Synthetics Industry and are not covered by this document.

[3] Chlorosulfonated and chlorinated polyethylenes should be considered part of the Plastics and Synthetics Industry. They are not covered by this document.

[4] Polysulfide rubbers are produced by a condensation-type reaction which is not directly comparable to either emulsion or solution polymerization. Per unit of rubber production, generated wastewaters are of considerably poorer quality and more troublesome to treat than those of either emulsion or solution or solution processes. Polysulfide rubber production is not covered by this document. It is recommended that a separate study be made of the polysulfide rubber industry.

Source: C. F. Ruebensaal, The Rubber Industry Statistical Report International Institute of Synthetic Rubber Producers, Inc.

Reproduction from EPA Development Document, February 1974.

For the purpose of establishing effluent limitations guidelines, the synthetic rubber industry has been divided into three subcategories: emulsion crumb, solution crumb, and latex. Crumb rubbers, generally for tires, are sold in a solid form, and are produced through two different processes: emulsion polymerization and solution polymerization. Latex rubbers, generally for specialty products, are sold in latex form, and are produced through emulsion polymerization.

Emulsion polymerization is the traditional and dominant process for producing synthetic rubber. The raw materials (monomers) are usually styrene and butadiene, to which a catalyst, activator, and modifier are added in a soap solution to produce an emulsion in an aqueous medium; polymerization proceeds step-wise through a train of reactors. The product rubber is formed in the emulsion phase of the reaction mixture, which is a milky white emulsion called latex. Unreacted monomers are then recovered from the latex by vacuum stripping; the production process ends at this point for latex rubbers. If crumb rubber is desired, sulfuric acid and sodium chloride are added to the latex to coagulate out the crumb rubber, which is then dewatered, rinsed, filtered, and finally dried with hot air to produce the final product.

The production of synthetic rubbers by solution polymerization is a step processing operation very similar to emulsion polymerization. For solution polymerization, the monomers must be extremely pure, and the solvent (hexane, for example) must be completely anhydrous. The polymerization reaction is more rapid (1 to 2 hours) and is taken to over 90 percent conversion as compared to 60 percent conversion for emulsion polymerization. Both monomers and solvents are generally passed through drying columns to remove all water. After reaction, the mixture leaves the reactor as a rubber cement; i.e. polymeric rubber solids dissolved in solvent. As with emulsion polymerization, coagulation, dewatering, and drying processes produce the final product.

Tire and tube products are produced in 56 plants in the United States; about 70 percent of these plants are operated by Firestone, General Tire, Goodrich, Goodyear, and Uniroyal. The remaining plants are operated by 11 other companies. Tire plants vary widely in capacity; the largest produce approximately 30,000 tires per day, and the smallest produces less than 5,000 per day.

Fourteen companies operating 28 plants produce the major synthetic rubbers in the United States. Most of these plants are part of diversified complexes that produce other products, such as rubber processing chemicals, plastics, and basic intermediate organic chemicals.

Waste Sources and Pollutants. The primary water useage in the tire and inner tube industry is for non-contact cooling and heating. Discharges from service utilities supplying cooling water and steam are the major source of contaminants in the final effluent. However, these non-process related discharges are not covered by the effluent limitations guidelines of this report. The process wastewaters consist of mill area oily waters, soapstone slurry and latex dip wastes, area washdown waters, emission scrubber waters, and contaminated storm waters from raw material storage areas, etc. For the purposes of establishing effluent limitations guidelines for manufacturers of tires and inner tubes, the following pollutant parameters have been designated as significant: suspended solids, oil and grease, and pH. Pollutant parameters considered to be of less significance are biochemical oxygen demand, chemical oxygen demand, dissolved solids, temperature (heat), and chromium.

The principal waste streams from synthetic rubber manufacture are steam and condensate from the monomer recovery stripping operation, overflow of coagulation liquors, and overflow of the crumb rubber rinse waters. Area washdown and equipment clean-out wastewaters are also major sources of pollutants, particularly in latex rubber plants where clean-up is more frequent because of smaller production runs. For manufacturers of synthetic rubbers, the following pollutant parameters have been designated as significant: chemical oxygen demand, biochemical oxygen demand, suspended solids, oil and grease, and pH. Pollutants also present in measurable quantities in the waste streams, but not designated as significant, include: total dissolved solids, surfactants, color, and temperature (heat).

Control Technology and Costs. In the tire and inner tube industry, the emphasis for present environmental control and treatment technologies is placed on the control of air quality and the reduction of pollutants in non-process wastewaters. As a result, no adequate overall control and treatment technology is employed by plants within the industry. Primary emphasis is on removal of separable solids from the non-process boiler blowdowns and water treatment wastes, and from process washdown waters from the soapstone area. Because of substantial dilution of process wastewater by non-process waters, treatment is much less effective than could be expected, especially for oil and grease.

End-of-pipe treatment generally involves the treatment of combined process and non-process wastewater in a primary sedimentation basin or lagoon.

Of 17 plants surveyed, four used chemical coagulation to further reduce solids levels. Six plants had some form of secondary treatment, either aerated lagoons, stabilization ponds, or activated sludge treatment, and four discharged to municipal systems. Only one plant performed totally adequate treatment of all process water streams by achieving no discharge through the use of spray irrigation and evaporation. In-process controls commonly employed include recirculation of soapstone solutions, elimination of drains in dirty areas, and the use of oil sumps or separators.

The technology recommended to meet the effluent limitations guidelines are:

1. Elimination of any discharge of soapstone solution by:
    - Recycling
    - Installation of curbing and the sealing of drains in the soapstone dipping area
    - Reuse the recirculating system washwater as make-up for fresh soapstone solution.
2. Elimination of any discharge of latex solution by:
    - Installation of curbing and the sealing of drains in the latex dipping area
    - Containment of all wastewaters in the area and disposal by landfill.
3. Segregation, control, and treatment of all oily waste streams.
4. Isolation of process waters from non-process wastewaters.
5. Treatment of process wastewaters with API-type gravity separators to remove separable oil and solids.
6. Additional treatment through an absorbent filter for further oil removal.

Existing control and treatment technology practiced by the synthetic rubber industry emphasized end-of-pipe treatment rather than in-plant reduction because in-plant modifications could affect processing techniques or the quality of the final product.

Current treatment technology for both emulsion crumb and latex plants involves primary clarification with chemical coagulation of latex solids, followed by biological treatment. As an alternative to chemical coagulation, air flotation clarification of primary and secondary solids is also practiced. Biological treatment systems include activated sludge, aerated lagoons, and stabilization ponds.

The control and treatment technology recommended to meet BPT and NSPS guidelines for emulsion crumb and latex plants is chemical coagulation and biological treatment, improved houskeeping and maintenance practices, as well as in-plant modifications, particularly the use of crumb pits to remove crumb rubber fines from coagulation liquor and crumb rinse overflows. BAT has been defined as BPT plus the equivalent of dual-media filtration followed by activated carbon treatment of the effluent from the biological treatment systems. Because solution crumb wastewaters do not contain uncoagulated latex solids, the chemical coagulation step is not necessary. BPT and NSPS technology for solution crumb plants have been defined as comparable to primary clarification and biological treatment, with the use of crumb pits to catch crumb rubber fines before treatment. BAT for solution crumb plants is the same as that for emulsion crumb plants.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	$86.3
Incremental BPT O&M	$ 8.1

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Principal reasons for differences between these cost estimates and the newer data are that G&P includes the industry subcategories in Phase II of the EPA Effluent Guidelines.

[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-20-2.
Rubber Processing
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity			
Old Tires Proc. (Units/Day)	1,025,786.	1,435,303.	1,539,463.
Synth. Rubber (Met. Tons/Day)	11,178.	14,158.	14,838.

Annual Growth Rate Over the Period 1976-1985 = 5.79%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS (except Rubber Reclaiming)	19.95	26.99	28.01
BOD5 (except Rubber Reclaiming)	9.91	12.89	13.65
Dissolved Solids (Latex Mfg. only)	0.76	0.94	0.98
Oils and Greases	3.91	5.29	5.66
COD (Syn. Rubber only)	41.03	55.52	59.39
Legislated Controls:			
TSS (except Rubber Reclaiming)	6.81	2.96	3.12
BOD5 (except Rubber Reclaiming)	3.15	1.05	1.11
Dissolved Solids (Latex Mfg. only)	0.20	0.02	0.02
Oils and Greases	1.34	0.63	0.67
COD (Syn. Rubber only)	15.23	8.62	9.18

CONTROL COSTS (Million 1975 $)		AGGREGATED OVER			
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	82.10	(BPT)	37.09	(BAT)	76.93
Pretreatment	0.00		0.00		0.00
New Plants	2.25		45.08		52.84
Municipal Investment Recovery	0.0		0.0		0.0
Totals	84.35		82.17		129.77

Annualized Costs	1977	1983	1985	1976-85

Table 4-20-2. (Continued)
Rubber Processing
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Capital[1]	11.09	21.89	22.89	166.72[2]
O&M[3]				
On-site Treatment	4.42	7.77	16.02	79.21
Pretreatment	0.0	0.0	0.0	0.0
Totals	4.42	7.77	16.02	79.21
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	15.51	29.67	38.92	245.93

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Rubber industry includes old and new tire processing, emulsion crumb and solution crumb processing, and latex rubber processes.

FERROALLOY INDUSTRY

Production Characteristics and Capacities. There were 44 plants in the United States in 1972 which produced ferroalloy manganese, chromium, and other additive metals.

The smelting and slag processing segments of the ferroalloy manufacturing industry are subdivided into three subcategories as follows: Subcategory I: open electric furnaces with wet air pollution control devices, Subcategory II: covered electric furnaces and other smelting operations with wet air pollution control devices, and Subcategory III: slag processing. In the first two subcategories, the main source of wastewater results from the air pollution scrubbers. In the third category, water is used only as a transport or cooling medium.

Submerged-arc electric furnaces operate continously as power is applied to the electrodes and they are supplied with materials that consist mostly of reducing material (coal or coke), iron and steel borings and turnings and ores that may be charged to the furnace on either a continuous or an intermittent basis. Due to the large volume of gases emitted, water-cooled covers collect the gases and reduce the amount of heat generated by the furnaces.

The four most important ferroalloys are: ferromanganese, ferrosilicon, ferrochromium, and silicomanganese. Ferroalloys are used to produce steels of greater strength and corrosion resistance, and in the deoxidation, alloying, and graphitization processing of steel and cast iron.

Waste Sources and Pollutants. The major wastewater source in the ferroalloy manufacturing industry results from the use of wet scrubbers (venturi-type) for air pollution control. Approximately one-third of the furnaces in the industry use such devices. The cooling of ferroalloy furnaces also required large quantities of water. Other sources of wastewater stem from boiler feed, air conditioning, and sanitary uses. Wastewaters result from slag processing operations in which slag is crushed and sized for recovery of metal values, or from slag shotting operations in which the slag is granulated for further use.

The primary wastewater effluents resulting from wet methods for air pollution control are: suspended insoluble metal compounds, soluble metal compounds, cyanides, acid or basic effluents, tars, and thermal discharges.

The basic parameters used in establishing water effluent guidelines are: suspended solids, total chromium, hexovalent chromium, total cyanide, manganese, phenol, and pH.

Control Technology and Costs. Current water pollution control and treatment technology used in the ferroalloy industry for those plants utilizing wet air pollution control devices has been through sedimentation of scrubber water in large lagoons. Hence, wastewaters are now being treated by physical means.

Best Practicable Technology for Subcategories I and II involves both physical and chemical treatment by means of sedimentation (clarifiers and flocculators) and chemicals such as: caustic or sulfuric acid solutions, sulfur dioxide, and chlorine dioxides. Also included is recycling of water at the scrubber to aid in removal of toxic pollutants. Process water quality requirements for Subcategory III are less stringent than the other two, but also requires sedimentation and chemical treatment when necessary.

Best Available Technology (and NSPS) for Subcategories I and II, in addition to BPT, includes recirculation of the wastewater, which necessitates the addition of sand filtration for suspended solids removal. Subcategory III, in addition to BPT, will require process water recirculation for suspended solids removal.

In order to compute the incremental capital costs to this industry, it is necessary to estimate the number of plants that have wet air pollution control devices. It is estimated that 32 percent have wet air pollution control, 38 percent have dry air pollution control, and 30 percent have no air pollution control.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The ferroalloy G&P estimates are as follows (in 1975 dollars):

Incremental BPT Investment	15.0
Incremental BPT O&M	5.0

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Principal reasons for the differences are industry definition expansion and changes in plant inventory estimates. Note that both studies agree to within 12 percent.

Table 4-21-1.
Ferroalloy
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity			
Slag Process (kkg/Day)	256.57	355.26	358.55
Ferrolloys (MW of Furnace Oper.)	2,129.	2,639.	2,669.

Annual Growth Rate Over the Period 1976-1985 = 4.07%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	4.52	5.70	5.79
Dissolved Solids	3.71	4.68	4.90
Nutrients	.12	.15	.16
Oils and Greases	.35	.44	.46
Legislated Controls:			
TSS	1.98	0.97	0.91
Dissolved Solids	1.81	0.18	0.15
Nutrients	.14	.08	.05
Oils and Greases	.41	.30	.24

CONTROL COSTS (Million 1975 $)		AGGREGATED OVER			
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	11.37	(BPT)	20.45	(BAT)	25.76
Pretreatment	0.00		0.00		0.00
New Plants	5.89		29.05		31.63
Municipal Investment Recovery	0.0		0.0		0.0
Totals	17.27		49.50		57.40

Table 4-21-1. (Continued)
Ferroalloy
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	2.27	8.78	8.90	57.65[2]
O&M[3]				
On-site Treatment	1.10	1.47	1.76	13.55
Pretreatment	0.0	0.0	0.0	0.0
Totals	1.10	1.47	1.76	13.55
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	3.37	10.25	10.67	71.19

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Ferroalloy industry includes open and covered electric arc furnaces and slag processing.

IRON AND STEEL INDUSTRY

Production Characteristics and Capacities. The iron and steel industry is one of the largest in the nation, comprising some 179 companies operating 420 plants; 23 steel companies operate approximately 65 integrated steel plants. These integrated plants represent about 90 percent of the total steel-making capacity. The balance of the steel-making capacity is represented by the non-integrated steel producers, many of whom are classified as mini-mills.

The iron and steel industry comprises the coking, blast furnace-sinter plant, iron casting, steel manufacturing, and steel casting segments. The industry is primarily engaged in manufacturing hot metal, pig iron, and ferroalloys from iron ore and iron and steel scrap, and in converting pig iron, scrap iron, and scrap steel into steel. Merchant blast furnaces and byproduct or beehive coke ovens are also included in the industry.

Three basic steps are involved in the production of steel First, coal is converted to pure carbon or coke. Second, coke is then combined with iron ore and limestone in a blast furnace to produce iron. Third, the iron is purified into steel in either an open-hearth, basic-oxygen, or electric-arc furnace. Further refinements include degassing by subjecting the steel to a high vacuum. Steel that is not cast in ingot molds can be cast in a process called continuous casting.

For the purpose of establishing effluent guidelines, the industry has been divided into 12 subcategories as follows:

- Byproduct coke
- Beehive coke
- Sintering
- Blast furnace (iron)
- Blast furnace (ferromanganese)
- Basic-oxygen furnace (semi-wet air pollution control methods)
- Basic-oxygen furnace (wet air pollution control methods)
- Open-hearth furnace

- Electric-arc furnace (semi-wet air pollution control methods)

- Electric-arc furnace (wet air pollution control methods)

- Vacuum degassing

- Continuous casting.

Basic-oxygen furnaces and open-hearth furnaces produce almost all of the steel; electric-arc furnaces are mostly mini-mills. Only seven electric-arc furnaces reported the use of "wet" air pollution control equipment. Hence, the effluent limitations guidelines apply mainly to the large, integrated mills.

The total annual raw steel capacity in 1972 of the iron and steel industry was approximately 1,070 million metric tons. Of this, the integrated mills accounted for approximately 154 million metric tons (94 percent).

Although the year-to-year production of raw steel has fluctuated widely, the average annual rate of growth over the past 15 years has been about 3.5 percent, from 84 million metric tons in 1959 to an estimated 136 million metric tons in 1973. This has been accomplished with a very modest establishment of new integrated mills, although many non-integrated "mini-mills" have been built. Most of the increase in capacity has been accomplished by upgrading capacities of existing steel plants, building larger blast furnaces, and replacing open-hearth furnaces with basic-oxygen furnaces.

Waste Sources and Pollutants. The principal source of wastewater pollutants from the iron and steel industry is cooling water. Enormous amounts of water are used in the steel-making process to cool furnaces and finished products, and to quench hot coke, slag, etc. Much of this is "once-through" cooling water, although blowdown from recirculating systems and barometric condenser water is also present. Water used in "semi-wet" air pollution control systems constitutes the second-most important source of wastewater from the iron and steel industry. Other significant sources of wastewater include excess ammonia liquor and light oil recovery wastes from byproduct coke-making, and gas cleaning water from blast furnace operation.

Pollutants covered by the effluent limitations guidelines are cyanide, phenol, ammonia, oil and grease, suspended solids, sulfide, fluoride, manganese, nitrate, zinc, lead, and pH. The guidelines apply to aqueous waste discharge only, exclusive of non-contact cooling waters.

Control Technology and Costs. Treatment control practices currently employed in the iron and steel industry may be summarized as follows:

Source	Treatment Control Practices
Ammonia liquors	Ammonia stripping, solvent recovery, detarring
Quenching	Settling followed by discharge or recycle
Gas cleaning	Thickening, alkaline chlorination, chemical coagulation, sometimes with settling or filtration followed by discharge or recycle
Vacuum degassing	Evaporative cooling or cooling towers, sometimes with settling or filtration followed by recycle
Continuous casting	Settling, filtration, evaporative cooling followed by recycle

The treatment technologies called for by the effluent limitations guidelines are summarized in Table 4-22-1.

The most recent analysis of costs for this sector was provided to the Environmental Protection Agency by Temple, Barker & Sloane, Inc.(TBS)[1]. This analysis was conducted in somewhat greater depth than, and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure, and is considered to be more precise. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The TBS estimates are as follows (in million 1975 dollars):

	Incremental Investment	Incremental O&M
1974-77	1,760	290
Phase I	250	30
Phase II	1,330	130
Storm Runoff	20	--
Other Water	160	30
1978-83	1,820	2,610
Phase I	400	420
Phase II	850	1,270
Storm Runoff	130	100
Other Water	440	820

The earlier SEAS calculations are presented in Table 4-22-2, with projected pollutant discharges associated with these costs. SEAS addresses only Phase I and Phase II costs. The Phase I investment costs of both studies are within approximately five percent of each other for 1974-1977, with Phase I investment costs over 1978-1983 approximately ten percent in difference. Phase II investment costs over 1978-1983 are extremely close--within three percent. However, the timing of the payments varies substantially between the two studies for Phase II.

While the total investment expenditures of both studies are remarkably similar for 1974-1983, significant differences exist in assignment of these costs to meeting BPT or BAT regulations. TBS states a BPT cost of $1,390 million, with an additional cost of $150 million for changes in construction, yielding a total estimate of $1,540 million for Phase I and Phase II investment costs. SEAS lists $865 million plus 108 million for expansion costs during this period for a total of $973 million. No estimate for changes in construction work is included in SEAS. Phase I cost estimates of TBS for meeting BPT regulations are lower than SEAS, whereas Phase II is substantially higher. This is because TBS estimates are derived from the more stringent guidelines issued by EPA in March 1976. SEAS Phase II cost estimates were based upon an earlier guideline outlined by EPA in August 1975. An additional source of variance in the cost projections is that TBS bases their forecasts upon projected 1983 production levels. SEAS uses estimates of 1972 production, and historical growth patterns of the industry to forecast future production.

[1] "Economic Analysis of Proposed and Interim Final Effluent Guidelines, Integrated Iron and Steel Industry", Temple, Barker & Sloane, Inc., March, 1976.

Table 4-22-1.
Iron and Steel Control Technologies

Subcategory	BPT	BAT	NSPS
Byproduct	Ammonia still operation with lime operation, dephenolization, sedimentation, neutralization.	BPT, less dephenolization plus sulfide oxidation, clarification, multi-stage biological oxidation with methanol addition (or alkaline chlorination and carbon adsorption), and pressure filtration.	Same as BAT.
Beehive coke	Settling basin with complete recycle and no aqueous blowdown.	Same as BPT.	Same as BPT.
Sintering	Thickener with chemical flocculation, tight recycle, surface skimming, neutralization.	BPT, plus lime precipitation of fluorides.	Same as BAT.
Blast furnace (iron)	Thickening with blymer addition, recycle using cooling tower.	BPT, plus alkaline chlorination, press use filtration, and carbon adsorption, neutralization.	Same as BAT.
Blast furnace (ferromanganese)	Thickening with blymer addition, scrubber water, recycle with evaporative cooling, pH adjustment.	Same as above.	Same as BAT.
Basic-oxygen furnace (semi-wet air pollution control methods)	Settling tank with chemical and/or magnetic flocculation, complete recycle and no aqueous blowdown.	Same as BPT.	Same as BPT.
Basic-oxygen furnace (wet air pollution control methods)	Classifier/thickener with chemical and/or magnetic flocculation, tight recycle, neutralization.	Blowdown treatment using lime precipitation of fluorides and sand filtration or improved settling with coagulation.	Same as BAT.

Table 4-22-1. (Continued)
Iron and Steel Control Technologies

Subcategory	BPT	BAT	NSPS
Open-hearth furnace	Same as above.	Same as above with anaerobic denitrification.	Same as BAT without denitrification.
Electric-arc furnace (semi-wet air pollution control methods)	Settling tank with chemical and/or magnetic flocculation with complete recycle and no aqueous blowdown, or controlled wetting of gases to form sludge only, no recycle or blowdown.	Same as BPT.	Same as BPT.
Electric-arc furnace (wet air pollution control methods)	Classifier/thickener with chemical and/or magnetic flocculation, tight recycle, neutralization.	Blowdown treatment using lime precipitation of fluorides and sand filtration or improved settling with coagulation.	Same as BAT
Vacuum degassing	Settling via classifier, tight recycle over a cooling tower.	Blowdown treatment with coagulation/clarification and anaerobic denitrification (or substitution of another gas for nitrogen), neutralization.	Same as BAT without denitrification.
Continuous casting	Scale pit with dragout conveyor, oil skimmer, flatbed filtration, recycle with cooling tower.	BPT, plus filtration or blowdown.	Same as BAT.

Source: EPA Development Document, June 1974.

Table 4-22-2.
Iron and Steel
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity:			
Phase I (MT/Day)	178,597.	206,751.	197,989.
Phase II (kkg/Day)	1,156,790.	1,249,267.	1,205,600.

Annual Growth Rate Over the Period 1976-1985 = 1.41%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	1,389.36	1,534.13	1,547.71
BOD$_5$ (Beehive & Byproduct Coking only)	26.42	28.46	28.61
Dissolved Solids	718.09	821.41	839.86
Nutrients (Open Hearth Fur. only)	.18	.10	.06
Bases (Beehive & Byproduct Coking, and Iron Foundry only)	186.82	201.54	202.66
Oils and Greases (Except Iron Foundry & Beehive Coking)	401.04	478.72	495.15
Legislated Controls:			
TSS	418.98	57.64	12.23
BOD$_5$ (Beehive & Byproduct Coking only)	10.42	3.02	2.41
Dissolved Solids	152.22	2.56	2.26
Nutrients (Open Hearth Fur. only)	.04	.02	.01
Bases (Beehive & Byproduct Coking, and Iron Foundry only)	58.77	4.97	2.10
Oils and Greases (Except Iron Foundry & Beehive Coking)	121.01	20.19	3.34

Table 4-22-2. (Continued)
Iron and Steel
Industry Data Summary

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER			
Phase I				
Investment	1974-77	1978-83	1976-85	
Existing Plants				
On-site Treatment	211.99 (BPT)	273.03 (BAT)	364.65	
Pretreatment	0.00	0.00	0.00	
New Plants	25.74	79.63	81.99	
Municipal Investment Recovery	0.0	0.0	0.0	
Totals	237.73	352.67	446.64	
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	31.26	77.62	77.35	534.13[2]
O&M[3]				
On-site Treatment	271.82	307.01	423.71	3,143.14
Pretreatment	0.0	0.0	0.0	0.0
Totals	271.82	307.01	423.71	3,143.14
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	303.07	384.63	501.05	3,677.27

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

Table 4-22-2. (Continued)
Iron and Steel
Industry Data Summary

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Iron and Steel (Phase I) industry includes byproduct coking; blast furnace production; electric arc, open hearth, and basic oxygen furnace operations; and continuous casting processes.

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Phase II					
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	652.73	(BPT)	1,211.09	(BAT)	1,516.49
Pretreatment	0.00		0.00		0.00
New Plants	82.36		291.41		304.64
Municipal Investment Recovery	0.0		0.0		0.0
Totals	735.09		1,502.50		1,821.13

	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	96.65	294.19	284.82	1.866.22[2]

Table 4-22-2. (Continued)
Iron and Steel
Industry Data Summary

O&M[3]				
On-site Treatment	151.93	188.58	257.47	1,871.60
Pretreatment	0.0	0.0	0.0	0.0
Totals	151.93	188.58	257.47	1,871.60
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	248.57	482.77	542.29	3,737.82

Phase II (Continued)

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Iron and Steel (Phase II) industry includes cold rolling, hot forming, pipe and tubing production, hot and cold coating process, and other chemical processing operations.

BAUXITE REFINING INDUSTRY

Production Characteristics and Capacities. There are nine domestic bauxite refineries owned by five primary aluminum producers. Bauxite refining is carried on only by these primary aluminum producers, ususally in very large-scale installations.

Size range distribution and alumina production capacities of the refineries are classified as: small (500,000 metric tons per year), medium (501,000 - 1,000,000 metric tons per year), and large (>1,000,000 metric tons per year).

The bauxite refining industry is a subcategory of the aluminum segment of the nonferrous metals industry. Bauxite is the principal ore of aluminum and the only one used commercially in the United States. It consists of aluminum oxide (hydrated) and contains various impurities, such as iron oxide, aluminum silicate, titanium dioxide, quartz, and compounds of phosphorous and vanadium. Two processes are used in alumina refining: Bayer process and combination process.

The Bayer process is classically used in the United States. Impure alumina in the bauxite is dissolved in a hot, strong alkali solution (generally NaOH), to form sodium aluminate. Upon dilution and cooling, the sodium aluminate hydrolyzes, forming a precipitate of aluminum hydroxide which is filtered and calcined (roasting or burning to bring about physical or chemical changes) to alumina (pure).

The combination process is applied to high-silica bauxites. It is similar to the Bayer process but includes an additional extracting step. This is accomplished by mixing the red mud residue from the prior step with limestone and sodium carbonate, and then sintering this mixture at 1100° to 1200°C. Silica is converted to calcium silicate and residual alumina to sodium aluminate. The sintered products are leached to produce additional sodium aluminate solution, which is either filtered and added to the main stream for precipitation or is precipitated separately. The residual solids (brown mud) are slurried to a waste lake.

Higher taxes and levies on imported bauxite have increased the interest in the possible use of alternative materials located in the United States to produce alumina. Efforts to use domestic sources of raw materials, such as clays, alunite, and anorthosite, are increasing, and a U.S. producer is now using a Soviet process termed successful in refining alumina from alunite.

Waste Sources and Pollutants. The primary waste from a bauxite refinery is the gangue (worthless rock) from the ore, known as red or brown mud, which is produced in large quantities. From about one-third to one ton of red mud will be produced per ton of alumina. An increase of 2 to 2-1/2 ton per ton occurs from brown mud.

The principal water streams in a bauxite refinery are the following: red mud stream, spent liquor, condensates, barometric condenser cooling water, and storm water runoff.

The major process waste is the mud residue. The Bayer process produces a red mud while the combination process treats this mud and forms a brown mud. However, these differences do not alter the problem of disposal.

Wastewater parameters used for determining effluent guidelines include: alkalinity, pH, total dissolved solids, total suspended solids, and sulfate. Mud residue resulting from process operations is produced on a large scale (500 to nearly 4,000 kkgs per day). Use of wastewater recycle systems, along with complete waste retention, will eliminate the discharge of all process wastewater pollutants to receiving waters.

The guidelines for all three levels of control (BPT, BAT and NSPS) are essentially no discharge of process wastewaters to navigable waters. To allow for certain climatic conditions, the guidelines permit a bauxite refining plant to discharge an amount of water equal to the amount by which rainfall exceeds the natural evaporation. This amount is applicable to only that rainfall landing directly in impoundment areas, such as active and dormant mud lakes and neutralization lakes.

Control Technology and Costs. Since enormous aqueous waste suspensions are generated in bauxite refining, no practicable or currently available treatment or control technology for these wastes exists, except for impoundment. In all but two plants, a large diked area for impounding the red mud has been made available. Wastes containing high alkalinity or acidity can be neutralized, but this leads to the creation of dissolved solids. Mud and other pollutants from refining, however, can be impounded in a red mud lake system. Cooling towers may be an alternative for the cooling water supply for barometric condenser effluents.

Two plants are known to be currently operating with no discharge of water. Four other plants have prepared or are implementing plans to achieve no discharge of process waters before the effective date of effluent limitations. Two plants are currently discharging all wastes, but are implementing plans to impound red mud.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The bauxite G&P estimates are as follows (in 1975 dollars):

Incremental BPT Investment	63.4
Incremental BPT O&M	6.7

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. G&P lists costs on a plant-by-plant basis, whereas SEAS utilizes model plants with associated average costs. This, combined with the capital in place assumptions of the computer model, resulted in different cost estimates.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972," National Bureau of Economic Research, December 1975. (Revised January 1976)

Table 4-23-1.
Bauxite Refining
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (1,000 MT/Yr)	7,276.	9,831.	10,041.

Annual Growth Rate Over the Period 1976-1985 = 4.82%

EFFLUENTS (1,000 Metric Tons)	1977	1983	1985
1971 Controls:			
TSS	2,182.10	2,771.80	2,923.85
Dissolved Solids	88.60	112.54	118.72
Legislated Controls:			
TSS	641.19	0	0
Dissolved Solids	26.03	0	0

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	34.86	(BPT)	0.0	(BAT)	15.85
Pretreatment	0.00		0.00		0.00
New Plants	15.36		60.71		67.98
Municipal Investment Recovery	0.0		0.0		0.0
Totals	50.22		60.71		83.83

Table 4-23-1. (Continued)
Bauxite Refining
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	6.60	14.58	14.94	114.66[2]
O&M[3]				
On-site Treatment	51.68	71.55	72.77	636.24
Pretreatment	0.0	0.0	0.0	0.0
Totals	51.68	71.55	72.77	636.24
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	58.29	86.13	87.71	750.91

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Bauxite Refining industry includes two alumina refining processes: Bayer and combination.

PRIMARY ALUMINUM SMELTING INDUSTRY

Production Characteristics and Capacities. The primary aluminum industry has three production stages: bauxite mining, bauxite refining to produce alumina (aluminum oxide), and the reduction of alumina to produce aluminum metal; this last state is commonly known as aluminum smelting.

The reduction of alumina to produce aluminum metal is carried out in electrolytic cells, or pots, that are connected in series to form a potline. The facility containing a number of potlines is referred to as the potroom. The electrolysis takes place in a molten bath composed principally of cryolite, which is a double fluoride of sodium and aluminum; alumina is added to the bath periodically. As electrolysis proceeds, aluminum is deposited at the cathode, and oxygen is evolved at the carbon anode. The oxygen reacts with the carbon to produce a mixture of carbon monoxide and carbon dioxide while the anode is consumed.

Two methods of replacing the anodes are practiced; they are referred to as the prebaked anode (intermittent replacement) and the Soderberg anode (continuous replacement). For either system, the anode preparation begins in the anode paste plant, where petroleum coke and pitch are hot-blended. For prebaked anodes, the anode paste is pressed in molds, and the anodes are baked in the anode bake plant. The baked anodes are used to replace consumed anodes, and the anode butts are returned to the anode preparation area. In the Soderberg anode system, the anode paste is not baked initially, but is fed continuously in the form of briquette through a shell into the pot. As the paste approaches the hot bath, the paste is baked in place to form the anode. Soderberg anodes are supported in the sleeves by vertical or horizontal studs.

The continuous evolution of gaseous reaction products from the aluminum reduction cell yields a large volume of fume that requires ventilation systems to remove it from the potroom. The ventilation air must be scrubbed to minimize air pollution and both dry and wet scrubbing methods are used for this purpose. Water from wet scrubbers, used for air pollution control on potroom ventilation air, is the major source of wastewater in the primary aluminum industry.

The liquid aluminum produced is tapped periodically, and the metal is cast in a separate cast-house facility. The molten metal is degassed before casting by bubbling chlorine or a mixed gas through the melt. The chlorine degassing procedure also produces a fume which must be scrubbed for air pollution control.

A few aluminum smelters have metal fabrication facilities, such as rod mills, rolling mills, etc., on the primary reduction plant site. Since these metal fabrication operations will be covered under separate effluent limitations, they are not covered by the effluent limitations derived for this report.

Waste Sources and Pollutants. As mentioned previously, the major source of wastewater in the primary aluminum smelting industry is the water used in air pollution control equipment (scrubbers) that are installed on potline and potroom ventilation air systems. Scrubbers are also used on anode bake furnace flue gas, and on cast-house gases. Other significant sources of wastewater include: cooling water used in casting, rectifiers, and fabrication; boiler blowdown; and storage area run-off, especially water contaminated with fluoride from spent cathodes.

The following pollutant parameters have designated the following significant pollutants from the primary aluminum smelting industry for the purposes of establishing effluent limitations guidelines: fluoride, total suspended solids, and pH. Other wastewater pollutants identifiable with the industry, but not considered significant, include: oil and grease, cyanide, dissolved solids, chloride, sulfate, chemical oxygen demand, temperature, and trace metals.

Control Technology and Costs. The existing technologies for controlling wastewater volume in this industry include dry fume scrubbing, and recycling of water to wet scrubbers after precipitation by lime or alum, absorption of activated alumina or hydroxylapatite, and reverse osmosis. Table 4-24-1 summarizes the present and potential control and treatment technologies for the primary aluminum smelting industry, as forecast by SEAS.

Table 4-24-1.
Primary Aluminum Smelting Industry Control Technology

Wastewater Source	Present Practice	Possible Added Control	Possible Added Treatment
Pot (primary) wet scrubber	Discharge without treatment	Convert to dry scrubbing	-
Pot (primary) wet scrubber	Discharge without treatment	Install cryolite or line pptn. plus recycle with bleed	Install lime treatment of bleed stream
Pot (primary) wet scrubber	Lime and settle once-through	Install recycle with bleed	Install alumina adsorption
Pot (primary) wet scrubber	Cryolite or line pptn. with recycle	-	Install lime treatment of bleed stream
Potroom (secondary) wet scrubber	Discharge without treatment	Install cryolite or line pptn. plus recycle	-
Potroom (secondary) wet scrubber	Lime and settle once-through	Install recycle	Install alumina adsorption
Cast house wet scrubber	Settle	Convert to alternate degassing	-
Anode bake plant plant wet	Settle	Recycle	Flocculate and aerate
Paste plant wet scrubber	Settle	Recycle	-
Cast house cooling	Discharge without treatment	Close loop	Cooling tower
Rectifier cooling	Discharge without treatment	Convert to air-cooled rectifiers	Cooling tower
Rainfall runoff	Discharge without treatment	Route to cryolite recovery and recycle	-

Reproduced from EPA Development Document; March 1974.

BPT includes the treatment of wet scrubber water and other fluoride-containing effluents to precipitate the fluoride, followed by settling of the precipitate and recycling of the clarified liquor to the wet scrubbers. A holding pond or lagoon might also be necessary to minimize the discharge of suspended solids. Precipitation methods currently available use cryolite and lime. Alternate control technologies, which can be employed to achieve the required effluent levels, include dry fume scrubbing, total impoundment, and reuse of effluent water by a companion operation.

The application of the BPT described above results in a relatively low-volume, high-concentration bleed stream from the recycling system. BAT is lime or calcium chloride precipitation treatment of the bleed stream to further reduce the discharge of fluorides. Use of this technology assumes the volume of fluoride-containing effluent is reduced to approximately 5,000 liters per metric ton of aluminum. Alternatively, volumes as high as 50,000 liters per metric ton of aluminum may be possible if the effluent is treated by absorption methods (activated alumina or hydroxylapatite).

NSPS technology assumes the application of dry fume scrubbing systems or, alternatively, wet scrubbing equipment together with total impoundment or total recycling of the scrubber water. The treatment for flouride and suspended solids removal is essentially the same as for BPT above. The NSPS require the restriction of the discharge volume to 835 liters per metric ton of aluminum with a final fluoride concentration of 30 mg per liter; or an equivalent combination of fluoride level and volume. Alternatives for reducing water use and pollutant levels include air-cooled, solid state rectifiers; molten metal degassing; and careful cleaning of the anode butts before recycling.

Approximately one-third of the primary aluminum smelting plants in the United States are currently operating with discharge levels of pollutants within the July 1977 guidelines.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	$28.7
Incremental BPT O&M	$ 7.0

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Several reasons for differences between these cost estimates and the newer data exist. One major discrepancy resulted from differences in the application of engineering estimates. SEAS and the EPA Development Document used exemplary plant data to derive average costs per plants, while G&P used each plant as a model for its size class. As a result, capital costs per ton of output were 60 percent higher in the G&P study. Another difference is due to estimates of "capital-in-place". G&P assumed that 70 percent was already installed as compared to a 30 percent level assumed by SEAS. O&M costs vary considerable due to the considerations affecting plant inventory and treatment levels as well as differences in attribution of the O&M to federal laws.

[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-24-2.
Primary Aluminum Smelting
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (MT/Day)	49,827.	62,759.	64,615.

Annual Growth Rate Over the Period 1976-1985 = 3.63%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	23.60	29.66	31.20
Dissolved Solids	21.35	26.84	28.23
Legislated Controls:			
TSS	6.85	1.18	.46
Dissolved Solids	7.61	1.62	.42

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER		
Investment	1974-77	1978-83	1976-85
Existing Plants			
On-site Treatment	39.13 (BPT)	24.35 (BAT)	43.92
Pretreatment	0.00	0.00	0.00
New Plants	0.0	0.0	0.0
Municipal Investment Recovery	0.0	0.0	0.0
Totals	39.13	24.35	43.92

Table 4-24-2. (Continued)
Primary Aluminum Smelting
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	5.14	8.35	8.35	65.90[2]
O&M[3]				
On-site Treatment	26.11	27.90	32.53	285.14
Pretreatment	0.0	0.0	0.0	0.0
Totals	26.11	27.90	32.53	285.14
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	31.26	36.25	40.88	351.04

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Primary Aluminum industry includes three major production stages: bauxite mining, bauxite refining, and alumina reduction.

SECONDARY ALUMINUM SMELTING INDUSTRY

Production Characteristics and Capacities. The secondary aluminum industry comprises an estimated 54 firms with 58 plants. Other sources list the industry as having more plants, but these numbers include sweaters, scrap dealers, and non-integrated fabricators. For purposes of this report, the number of plants reported excludes these portions of the industry as they do not employ any of the processes included in the effluent limitations guidelines.

The secondary aluminum smelting industry is a subcategory of the aluminum segment of the nonferrous metals manufacturing category. This industry recovers, processes, and remelts various grades of aluminum-bearing scrap to produce metallic aluminum or an aluminum alloy as a product, which is used primarily to supply the following industries: construction, aircraft, automotive, electrical equipment, beverage cans, and fabricated metal products, which include a wide variety of home consumer products. The largest user of secondary aluminum ingot is the automotive industry.

The estimated 1973 capacity was 966,572 metric tons. The top four firms (Alcoa, Reynolds, Kaiser, and Ormet) account for about 50 percent of the capacity.

Waste Sources and Pollutants. Wastewaters are generated by the following processes: (1) ingot cooling and shot quenching, (2) scrubbing of furnace fumes during demagging, and (3) wet milling of residues or residue fractions. Secondary aluminum ingot is produced to specifications; melting to specification is achieved mainly by segregating the incoming scrap into alloy types. The magnesium content can be removed with a chlorine-gas treatment in a reverberating furnace.

The following are the primary wastewater pollutants discharged by the above processes: oil and grease, suspended and dissolved solids, and salts of aluminum and magnesium.

In metal cooling, molten metal in the furnace is usually either cast into ingot or sow molds or is quenched into shot. When cooling water is generated, ingot molds are sprayed while on conveyor belts to solidify the aluminum and allow its ejection from the mold. Shot is solidified by having metal droplets fall into a water bath. The wastewater generated is either vaporized, discharged to municipal sewage or navigable waters, recycled for some period and discharged (6-month intervals), continuously recycled with no discharge, or discharged to holding ponds.

Fume scrubbing results when aluminum scrap contains a higher percentage of magnesium than is desired for the alloy produced. Magnesium removal, or "demagging," is accomplished by either passing chlorine through the melt (chlorination) or with aluminum fluoride. While magnesium is extracted, heavy fuming results from demagging, which requires passing the fumes through a wet scrubbing system. Water used in scrubbing gains pollutants, primarily in the scrubbing of chlorine demagging fumes.

Residue processing takes place in the industry since residues are composed of 10 to 30 percent aluminum, with attached aluminum oxide fluxing salts (mostly NaCl and KCl), dirt, and various other chlorides, fluorides, and oxides. The metal is separated from the non-metals by milling and screening, which is performed wet or dry. In wet milling, the dust problem is minimized but the resulting waste stream is similar to scrubber waters in make-up but more concentrated in dissolved solids. Water is passed into a settling pond before discharge.

The major wastewater parameters stem from two wastewater streams: wet milling of residues and fume scrubbing. Wet milling of residues include: total suspended solids, fluorides, ammonia, aluminum, copper, COD, and pH. Fume scrubbing includes: total suspended solids, COD, and pH.

Control Technology and Costs. Approximately 10 percent of the industry is currently discharging directly to navigable waters. The majority of the industry discharges effluents into municipal treatment works, usually with some treatment.

Currently, some plants are utilizing various control alternatives for each of the three major wastewater sources. The control technologies required to meet BPT and BAT are as follows:

BPT

- Metal Cooling. Air cooling or continuous recycling of cooling water with periodic removal, dewatering, and disposal of sludge.

- Fume Scrubbing. Chlorine fume scrubbing (for magnesium removal using chlorine): pH adjustment and settling. Fluoride fume scrubbing (for magnesium removal using aluminum fluorides): pH adjustment, settling, and total recycling.

- Residue Milling. pH adjustment with settling and water recycle.

BAT

- Metal Cooling. Air cooling, water cooling (for complete evaporation) and total use and recycle of cooling water by use of settling and sludge dewatering.

- Fume Scrubbing. Use of aluminum fluoride for magnesium removal, and entrapment of fumes without major use of water, using alternatives such as the Alcoa process, Derham process or the Tesisorb process.

- Residue Milling. Dry milling, and a water recycle, evaporation, and salt reclamation process.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	$2.5
Incremental BPT O&M	$0.6

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Several reasons for differences between these cost estimates and the newer data exist. One major discrepancy resulted from differences in the application of engineering estimates. SEAS and the EPA Development Document used exemplary plant data to derive average costs per plants, while G&P used each plant as a model for its size class. O&M costs vary considerable due to the considerations affecting plant inventory and treatment levels as well as differences in attribution of the O&M to federal laws.

PRIMARY COPPER INDUSTRY

Production Characteristics and Capacities. The primary copper industry includes establishments primarily engaged in smelting copper from ore and in refining copper by electrolytic or other processes. Operations involving the mining of copper ore, as well as the rolling, drawing, and extruding of copper, are not included in this industry category. The basic process used by the primary copper industry is pyrometallurgical. Copper concentrates are fed to the primary smelter, which produces "blister copper" after roasting, smelting, and converting. The blister copper is then purified by fire-refining. If additional purification is required, an electrolytic process is employed, with the final product being cathode copper. Byproducts, such as gold and silver which were contaminants of the blister copper, are collected as "slimes" during electrolytic refining and are subsequently recovered.

In the roasting operation, the copper concentrates are subjected to controlled heat to burn away sulfur and other impurities. The copper silicate thus produced is then charged to a reverberatory or an electric furnace along with scrap copper, recycled slab, and fluxing materials to produce a copper-iron-sulfide material called matte. The liquid matte is then converted to a relatively impure form of copper called blister copper by an oxidation process involving the blowing of thin streams of air through the molten material.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-25-1.
Secondary Aluminum Smelting
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (MT/Yr)	1,995,700.	2,850,170.	3,056,733.

Annual Growth Rate Over the Period 1976-1985 = 5.80%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	2.52	3.60	3.94
COD	1.02	1.46	1.60
Dissolved Solids	1.37	1.96	2.15
Bases	19.26	27.47	30.09
Legislated Controls:			
TSS	2.02	.67	0
COD	.27	.03	0
Dissolved Solids	.66	.17	0
Bases	5.01	.52	0

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	14.20	(BPT)	34.14	(BAT)	40.00
Pretreatment	0.00		0.00		0.00
New Plants	6.55		17.56		23.04
Municipal Investment Recovery	0.0		0.0		0.0
Totals	20.76		51.70		63.04

Table 4-25-1. (Continued)
Secondary Aluminum Smelting
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	2.73	9.53	9.92	57.32[2]
O&M[3]				
On-site Treatment	6.21	8.55	10.83	78.58
Pretreatment	0.0	0.0	0.0	0.0
Totals	6.21	8.55	10.83	78.58
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	8.94	18.08	20.75	135.90

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Secondary Aluminum industry includes ingot and wet-milling processes.

In the fire-refining process, air is introduced beneath the molten copper in reverberatory or cylindrical furnaces. Sulfur dioxide passes off as a gas, and metal oxides appear in a slag which is skimmed off. The remaining metal is then deoxidized by the addition of coke and by insertion of large poles of green hardwood, which decompose into reducing gases; alternatively, natural gases may be used to reduce the cuprous oxide. Almost all fire-refined copper is cast into anodes for electrolytic refining. In this process, copper is separated from impurities by electrolytic dissolution at the anode and disposition of the pure metal at the cathode; the electrolyte used is usually a dilute solution of sulfuric acid and copper sulfate.

Waste Sources and Pollutants. The primary copper industry generates wastewater in the following processes or operations:

1. Slag granulation, i.e. spraying molten slag with jets of water to produce slag granules.

2. Blowdown from the sulfuric acid plants used to control sulfur dioxide emissions.

3. Water used to cool fire-refined copper, anode copper, shot copper, and various forms of cathode copper casting.

4. Refining operations such as disposal of spent electrolyte, electrolytic refinery washing, and slimes recovery.

5. Miscellaneous operations such as blowdown from scrubbing system, slurry overflow from dust collection systems, plant washdown, and byproduct scrubbing.

6. Storm water run-off commingling with process wastewaters.

Non-process water uses, such as non-contact cooling water and water used in on-site power generation, are also possible sources of wastewaters, but they are not covered in the effluent guidelines.

Wastewater constituents, which have been determined to be present in the process wastewaters of the primary copper industry in sufficient quantities to warrant their control and treatment, are as follows: total suspended solids, arsenic, cadmium, copper, lead, selenium, zinc, oil and grease, and pH. Other pollutant parameters which may be present include dissolved solids, sulfate, chloride, other metals, cyanide, chemical oxygen demand, and temperature (heat).

For the purpose of establishing effluent limitations guidelines, the primary copper industry has been divided into three subcategories:

1. Primary copper smelters including refineries located on-site with smelters.

2. Primary copper refineries located in areas of net evaporation.

3. Primary copper refineries located in areas of net rainfall.

The effluent limitations for the first two subcategories for BPT, BAT, and NSPS guidelines are essentially no discharge of process water pollutants into navigable waters except:

1. A volume of wastewater equivalent to that which falls within a properly-designed impoundment in excess of that attributable to a 10-year, 24-hour rainfall event.

2. During any calendar month a volume of wastewater equivalent to the difference between the precipitation for that month which falls within the impoundment and the evaporation for that month (or the difference between the means of precipitation and evaporation established for the area).

Control Technology and Costs. Most of the primary copper industry employs judicious practices to control the volume of wastewater discharged. Very little, if any, process wastewaters are discharged at most operations. Primary copper smelters, because of the integration of their operations, have numerous possibilities for process wastewater controls. Refineries with no on-site smelting operations do not have available all of these possible control approaches. The following list summarizes some of the alternatives available for controlling wastewaters discharged from the principal sources in the industry:

1. Slag granulation. Conversion to slag dumping; recycle and/or reuse of wastewaters.

2. Acid plant blowdown. Reuse and minimization of blowdown by reducing particulate load and heat.

3. Contact cooling water. Minimizing "temperature" bleed by providing sufficient cooling ponds or towers; recycling and/or reuse; use of air cooling.

4. Refinery wastes. Converting from vacuum evaporators to open evaporators; sale of spent electrocyle; recyle and/or reuse of spent electrolyte, electrolytic refining washing, and scrubber waters; reuse of washdown waters; segregation and retention of storm water runoff.

The treatment of wastewater streams prior to discharge in the primary copper industry normally includes neutralization and precipitation, additional chemical precipitation, and oil and grease removal by skimming where necessary. Advanced technologies with possible applications include reverse osmosis, ion exchange, evaporation, carbon adsorption, deep-well disposal, and fixation as a solid.

The control technologies recommended for primary copper smelters and for primary copper refineries in areas of net evaporation consist of the elimination of water discharge through the use of recycling or reuse, and other technologies, such as those listed above, and the use of impoundment with disposal by solar evaporation.

Disposal sources, such as the reuse of process waters at on-site mining, milling, and smelting operations are not available to refineries not provided with smelters. Consequently, control technology recommended for BPT guidelines consists of reduction of process wastewater volumes through recycling, reuse, etc., as discussed above, plus the liming and settling of resultant effluents. To meet BAT and NSPS guidelines, a continued reduction in the volume of process waters is recommended.

Most of the facilities in the primary copper industry currently discharge very little wastewater.

Annualized costs are summarized in Table 4-26-1. Although this report does not include an industry summary for Secondary Copper, Table 4-26-2 summarizes industry data, including investment and control costs.

Table 4-26-1.
Primary Copper
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (MT/Yr)	3,362,460.	4,140,470.	4,186,710.

Annual Growth Rate Over the Period 1976-1985 = 3.17%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	4.90	6.09	6.34
Dissolved Solids	1.40	1.74	1.81
Oils and Greases	.05	.06	.06
Legislated Controls:			
TSS	1.24	.01	.003
Dissolved Solids	.37	.01	.003
Oils and Greases	.02	.004	.001

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	2.69	(BPT)	3.18	(BAT)	4.17
Pretreatment	0.00		0.00		0.00
New Plants	0.86		3.56		3.65
Municipal Investment Recovery	0.0		0.0		0.0
Totals	3.54		6.74		7.82

Table 4-26-1. (Continued)
Primary Copper
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	0.47	1.35	1.36	9.52[2]
O&M[3]				
On-site Treatment	1.95	3.20	7.19	34.94
Pretreatment	0.0	0.0	0.0	0.0
Totals	1.95	3.20	7.19	34.94
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	2.42	4.56	8.55	44.47

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Primary Cooper industry includes ore smelting processes and refining operations.

Table 4-26-2.
Secondary Copper
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (MT/Yr)	1,224,260.	1,555,270.	1,591,780.

Annual Growth Rate Over the Period 1976-1985 =3.68%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	56.16	69.69	72.66
Dissolved Solids	8.20	10.18	10.61
Oils & Greases	0.23	0.28	0.29
Legislated Controls:			
TSS	13.98	0.0	0.0
Dissolved Solids	2.04	0.0	0.0
Oils & Greases	0.06	0.0	0.0

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	9.03	(BPT)	0.0	(BAT)	3.43
Pretreatment	0.00		0.00		0.00
New Plants	0.90		3.92		4.07
Municipal Investment Recovery	0.0		0.0		0.0
Totals	9.92		3.92		7.50

Table 4-26-2. (Continued)
Secondary Copper
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	1.30	1.82	1.84	16.06[2]
O&M[3]				
On-site Treatment	6.82	9.71	9.81	87.86
Pretreatment	0.0	0.0	0.0	0.0
Totals	6.82	9.71	9.81	87.86
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	8.12	11.53	11.65	103.93

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

PRIMARY LEAD INDUSTRY

Production Characteristics and Capacities. The primary lead industry includes establishments that are primarily engaged in smelting lead from ore and in refining lead by any process. Those establishments that are primarily engaged in the mining or milling of ores, and in rolling, drawing, and extruding lead are not included in this industrial category.

Primary lead in the United States is recovered entirely from sulfide ores, which are associated with other minerals, principally zinc, copper, and silver. The sequence of lead smelting and refining processes are: charge preparation (blending of the concentrate with flux and a variety of recycling products, including dust from collection systems, fumes, etc.), pellitzing, sintering, blast furnace smelting, and the subsequent refining operations to remove, and in some cases recover, metallic impurities. In the sintering process, the pellets of ore concentrate are burned to remove sulfur and other impurities, and to produce "sinter" of suitable size and strength for subsequent treatment in the blast furnace. By a combination of heat and reducing gases in the blast furnace, the sinter, recycled slag, etc., are separated into two constituent phases: molten metal and slag. The metals that are easily reduced, such as lead, copper, silver, gold, bismuth, antimony, and arsenic, become part of the metal phase. Refining operations include: drossing, the cooling of the molten lead so that excess copper floats to the surface; softening, either by air oxidation or by slag oxidation to remove antimony; and fire refining methods, where the molten lead is treated with zinc or with calcium and magnesium to form gold, silver, and bismuth compounds which float to the surface.

The primary lead industry consists of five domestic lead smelters and five refineries, three of which are located on-site with smelters.

The major uses of lead in the United States are as follows: batteries-36 percent, gasoline additives-19 percent, alloys and miscellaneous-27 percent, pipe and sheet-4 percent, pigments-9 percent, and cable-5 percent. Lead useage is heavily dependent upon the automobile industry. At present, the continued use of ackyl-lead compounds as gasoline additives is in question; this market might eventually be eliminated. Basically, lead has no substitutes in its numerous alloy, pipe, and sheet uses; its growth in these markets is closely tied to the growth of the construction industry.

Waste Sources and Pollutants. The principal sources of wastewaters from the primary lead industry are as follows:

- Blowdown from the sulfuric acid plants used to control sulfur dioxide emissions from sintering operations (three plants).
- Streams from blast furnace slag, speiss, and/or dross granulation. Molten slag, dross, etc., is granulated by impacting the molten stream with a high-pressure water jet. Usually the wastewater streams are intermittent overflows or bleed streams from a recirculating water system (five plants).
- Wastewaters from wet scrubber equipment used in the control of air pollution (four plants).

Various applications of non-contact cooling water are also found in primary lead smelters, but these non-contact streams are not covered by the effluent limitations guidelines.

A broad range of pollutants are found in the wastewater streams from primary lead smelters and refiners. The following pollutants have been found to occur in sufficient quantities to warrant their control and treatment: total suspended solids, cadmium, mercury, lead, zinc, and pH. Other pollutants that may be present include arsenic, chemical oxygen demand, cyanide, oil and grease, temperature (heat), dissolved chlorides, fluorides, phosphates, carbonates, calcium, magnesium, bismuth, and other metals.

Control Technology and Costs. Wastewater pollution control practices in the primary lead industry consist of in-process controls designed to reduce the volume of wastewater discharged and end-of-pipe systems to treat the wastewaters before discharge. Control practices currently used in the industry to reduce water discharges include: segregation of waste streams, recycling slag granulation water, recycle and reuse scrubber water, and good housekeeping provisions for the control of leaks and spills, stormwater run-off, pond failure, etc. Wastewater treatment technology normally involves lime precipitation of heavy metals. Additional treatment methods which could be employed include: hydrogen sulfide treatment to precipitate heavy metals, reverse osmosis to remove ionic materials, and evaporation.

The effluent limitations guidelines for the primary lead industry are based upon maximum use of water recycling and reuse plus the treatment of discharged wastewaters by lime neutralization and clarification.

Five of the seven plants in the primary lead industry have either already achieved no discharge of process wastewater pollutants, or are very near and anticipate reaching this goal. The two plants currently discharging process wastewater are geographically located in areas of net precipitation and operate metallurigical sulfuric acid plants.

Annualized costs are detailed in Table 4-27-1.

Table 4-27-1.
Primary Lead
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (MT/Yr)	1,653,065.	2,051,260.	2,128,640.

Annual Growth Rate Over the Period 1976-1985 = 3.44%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	0.02	0.03	0.03
Dissolved Solids	0.01	0.01	0.01
Legislated Controls:			
TSS	0.01	0.01	0.01
Dissolved Solids	0.004	0.003	0.003

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	2.52	(BPT)	0.0	(BAT)	1.16
Pretreatment	0.00		0.00		0.00
New Plants	0.15		1.95		2.16
Municipal Investment Recovery	0.0		0.0		0.0
Totals	2.67		1.95		3.31

Table 4-27-1. (Continued)
Primary Lead
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
	1977	1983	1985	1976-85
Annualized Costs				
Annualized Capital	0.35	0.61	0.63	4.98[2]
O&M[3]				
On-site Treatment	3.74	4.68	5.02	43.23
Pretreatment	0.0	0.0	0.0	0.0
Totals	3.74	4.68	5.02	43.23
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	4.09	5.28	5.66	48.21

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Primary Lead industry includes ore smelting and refining processes.

PRIMARY ZINC INDUSTRY

Production Characteristics and Capacities. The primary zinc industry consists of establishments that are primarily engaged in smelting zinc from ore or in refining zinc by any process. Establishments that are primarily engaged in the mining of zinc ore, or the rolling, drawing, and extruding of zinc are not included. The U.S. primary zinc industry includes both electrolytic and pyrometallurgical retort plants. Processes involved in the smelting and refining of zinc include roasting, sintering, reduction, and refining. In the roasting operation, the zinc concentrate is heated in an oxidizing atmosphere to burn off sulfur, lead, and other impurities. For pyrolytic or retort plants, roasting is followed by sintering in which the roasting product, calcine, is heated together with various residues and zinc oxide materials to further reduce impurities and to produce a more compact feed for the retort furnaces. In the reduction process, heating of the sinter in a reducing atmosphere removes most of the zinc oxide. Refining the zinc includes processes that are designed to further purify the zinc; for example, by reducing the temperature of the molten zinc so that iron and lead precipitate or by distillation of the molten zinc.

For the electrolytic reduction of zinc, sintering is not necessary. However, acid washing of the zinc concentrate is necessary before roasting to remove magnesia. Before reduction, the calcine from roasting is leached with the spent sulfuric acid electrolyte to dissolve the zinc and to precipitate impurities. The purified solution is then introduced into electrolytic cells where zinc is deposited from the solution onto aluminum cathodes; the zinc cathode is then washed and sent to the casting plant.

The zinc industry is comprised of four electrolytic (one recently converted) and three pyrometallurgical retort plants. U.S. production of zinc has declined from 916,977 metric tons in 1967, to 562,340 metric tons in 1974. Half of the 14 plants operating in 1969 have closed; however, one plant in Illinois reopened in 1973 and additional plant capacity is expected. The retort plant in Amarillo, Texas, is scheduled to close, but two new plants have been announced.

Waste Sources and Pollutants. Two major sources of process wastewaters have been identified as common to all plants in the primary zinc industry:

- Blowdown from the sulfuric acid plants used to control emissions of sulfur dioxide from roasting operations;

- Metal casting cooling water.

Other sources of wastewaters identified for some plants include: scrubber water used to wash gases emitted from pyrolytic reduction furnaces, spent liquor from cadmium leaching, and scrubber water from dust control streams. The industry also uses a great deal of non-contact cooling water, but these wastewater streams are not covered by the guidelines.

The wastewater parameters which have been determined for the process wastewaters of the primary zinc industry and warrant control and treatment are: total suspended solids, arsenic, cadmium, mercury, selenium, zinc, and pH. Other pollutant parameters which also may be considered include: dissolved solids, chemical oxygen demand, lead, nickel, copper, cyanide, and temperature (heat).

Control Technology and Costs. The current treatment practices applied to process wastewater streams in the primary zinc industry include both settling and lime-and-settle of either segregated unit process streams or total plant effluents. Control measures currently used include recycling with bleed-off and reuse of wastewater. Additional treatment methods that could be employed for further reduction of pollutants include: hydrogen sulfide treatment for further precipitation of heavy metals, reverse osmosis to concentrate ionic materials, evaporation, and chemical fixation.

BPT guidelines are: the minimization of discharge or process wastewater recycling, reuse, or segregation; and chemical treatment to achieve controlled precipitation, followed by sedimentation (lime and settle). Specifically recommended control measures include:

1. The minimization of acid plant blowdown by appropriate proper operation of prescrubber gas and cleaning facilities to minimize particulate loadings into the wet scrubbers, cooling capacity and provisions for settling in the scrubber liquor recycle circuit, and possible reuse of the scrubber bleed stream in other plant operations.

2. The minimization of metal casting cooling water discharge by recycling, possibly including provisions in the circuit for removal of suspended solids, oil and grease, and thermal loads.

3. The exploitation of the evaporative capacity of hot gases or hot metal for in-plant disposal of wastewater.

Technology recommended to meet BAT and NSPS is analogous to the above technology, and includes control measures to further minimize the volume of process wastewater streams by additional recycling, reuse, segregation and the application of chemical treatment to achieve controlled precipitation, followed by sedimentation.

One plant in the primary zinc industry has already achieved no discharge of wastewater pollutants and another is very close to closure; of the remaining plants, four have lime and settle treatment systems.

Annualized costs are summarized in Table 4-28-1.

Table 4-28-1.
Primary Zinc
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (MT/Yr)	1,731,999.	2,177,362.	2,239,200.

Annual Growth Rate Over the Period 1976-1985 = 3.46%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	0.74	0.90	0.95
Dissolved Solids	1.15	1.40	1.46
Legislated Controls:			
TSS	0.31	0.18	0.16
Dissolved Solids	0.29	0.02	0.03

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	7.18	(BPT)	9.38	(BAT)	12.27
Pretreatment	0.00		0.00		0.00
New Plants	0.64		5.19		5.54
Municipal Investment Recovery	0.0		0.0		0.0
Totals	7.82		14.57		17.81

Table 4-28-1. (Continued)
Primary Zinc
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	1.03	2.94	2.99	19.89[2]
O&M[3]				
On-site Treatment	2.81	4.57	10.48	49.48
Pretreatment	0.0	0.0	0.0	0.0
Totals	2.81	4.57	10.48	49.48
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	3.84	7.52	13.47	69.37

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Primary Zinc industry includes ore smelting and refining processes.

ASBESTOS MANUFACTURING INDUSTRY

Production Characteristics and Capacities. There were 68 plants operating in the asbestos manufacturing industry in 1972. A majority of these asbestos plants incur wastewater during production.

With the exception of roofing and floor tile manufacturing, there is a basic similarity in the manufacturing methods of various asbestos products. The asbestos fibers and other raw materials are slurried with water and then formed into sheets. Save-alls (settling tanks) are used in all processes. In roofing manufacture, asphalt or coal tar is soaked into asbestos paper. In floor tile manufacture, asbestos is added to the tiles for its special structural and dimension-holding qualities.

Asbestos cement products are the largest overall user of asbestos fibers, and cement pipe is the largest producer in this category. Asbestos sheet is used for laboratory table tops and other structural uses. Asbestos paper and millboard have a great variety of uses, but it is particularly used for applications where direct contact with high temperatures occur. Asbestos roofing and floor tiles are essentially fabricated products that take advantage of the unique qualities of asbestos.

A favorable trade balance may be projected for asbestos products, regardless of any price effects resulting from the effluent standards. However, there has been a recent trend towards an increase in the value of imports, with an increase from $8.8 million in 1969 to $11.3 million in 1972.

Waste Sources and Pollutants. Asbestos manufacturing wastes include: total suspended solids, $BOD\underline{5}$, COD, pH (alkalinity), high temperature, total dissolved solids, nitrogen, phosphorous, phenols, toxic materials, oil and grease, organic matter, nutrients, color, and turbidity.

The major source of industry wastewater is the machine that converts slurry into the formed wet product. Water is used as: an ingredient, a carrying medium, for cooling, and for auxilliary uses such as pump seals, wet saws or for pressure-testing the pipes. In most plants, wastewater is combined and discharged into a single sewer. In all subcategories, water is removed during various steps to the save-all system (settling tank). Waste characteristics are defined by the following parameters: total suspended solids (TSS), COD, and pH.

Municipal discharge by subcategories is as follows: pipe-21 percent, sheet-46 percent, paper-42 percent, millboard-57 percent, roofing-44 percent, and floor tiles-54 percent. Total discharge by subcategories is: pipe-11 x 10^6lpd, sheet-7 x 10^6lpd, paper-20 x 10^6lpd, millboard-5 x 10^6lpd, roofing-2.2 x 10^6lpd, and floor-tile-7.4 x 10^6lpd.

Control Technology and Costs. Waste treatment methods used in the asbestos industry are summarized in Table 4-29-1.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	$1.4
Incremental BPT O&M	$0.2

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Principal reasons for differences between these cost estimates and the newer data are the levels of discharge to municipal treatment systems. The sources using municipal treatment incur a lower capital cost requirement (municipal investment recovery) than do plants having on-site treatment.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-29-1.
Asbestos Manufacturing Industry
Waste Treatment Methods

Subcategories	Sedimentation & Neutralization	Complete Recycle
Asbestos Cement Pipe		
BPT	X	
BAT		X
NSPS	X	
Asbestos Cement Sheet		
BPT	X	
BAT		X
NSPS		X
	Sedimenation & Coagulation	Complete Recycle
Asbestos Paper		
BPT	X	
BAT		X
NSPS		X
	Sedimentation (Elastomeric binder)	Complete Recycle (Starch binder)
Millboard		
BPT		X
BAT		X
NSPS		X
	Sedimentation & Skimming	Complete Recycle
Roofing		
BPT	X	
BAT		X
NSPS		X
Floor Tile		
BPT	X	
BAT		X
NSPS		X

Table 4-29-2.
Asbestos Manufacturing
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (MT/Day) Phase I	21,595.	26,956.	27,604.
(Liters/Day) Phase II	217,424.	333,810.	341,825.

Annual Growth Rate Over the Period 1976-1985 = 3.18%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	0.97	1.22	1.28
BOD5	0.09	0.11	0.12
COD	0.001	0.001	0.001
Dissolved Solids	13.05	16.34	17.09
Bases	3.67	4.60	4.81
Legislated Controls:			
TSS	0.59	0.13	0
BOD5	0.09	0.03	0
COD	0.001	0	0
Dissolved Solids	14.30	4.18	0
Bases	1.01	0	0

CONTROL COSTS (Million 1975 $)		AGGREGATED OVER	
Phase I			
Investment	1974-77	1978-83	1976-85
Existing Plants			
On-site Treatment	4.64 (BPT)	0.08 (BAT)	2.08
Pretreatment	0.00	0.00	0.00
New Plants	0.30	1.36	1.40
Municipal Investment Recovery	0.0	0.00	0.00
Totals	4.94	1.44	3.48

Table 4-29-2. (Continued)
Asbestos Manufacturing
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Phase I (Continued)				
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	0.65	0.66	0.68	3.69[2]
O&M[3]				
On-site Treatment	2.47	3.81	6.92	38.14
Pretreatment	0.0	0.0	0.0	0.0
Totals	2.47	3.81	6.92	38.14
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	3.12	4.47	7.60	41.65

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Asbestos industry includes the production of roofing and floor tile, sheet materials, and cement products.

Table 4-29-2. (Continued)
Asbestos Manufacturing
Industry Data Summary

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER			
Phase II				
Investment	1974-77	1978-83	1976-85	
Existing Plants				
On-site Treatment	0.26 (BPT)	0.08 (BAT)	0.08	
Pretreatment	0.00	0.00	0.00	
New Plants	0.24	0.02	0.02	
Municipal Investment Recovery	0.0	0.0	0.0	
Totals	0.50	0.10	0.10	
	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	0.07	0.08	0.08	0.72[2]
O&M[3]				
On-site Treatment	0.04	0.06	0.10	0.60
Pretreatment	0.0	0.0	0.0	0.0
Totals	0.04	0.06	0.10	0.60
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	0.11	0.13	0.18	1.33

Table 4-29-2. (Continued)
Asbestos Manufacturing
Industry Data Summary

Phase II (Continued)

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

CEMENT INDUSTRY

Production Characteristics and Capacities. The cement industry is comprised of three subcategories, which operate in two basic manufacturing processes, wet and dry, and materials storage runoff:

- Wet process leaching plants. The kiln dust comes into direct contact with water in the leaching process for reuse and from the wet scrubbers that control stack emission.
- Non-leaching plants. The contamination of water not associated with the water usage.
- Pile materials. Kiln dust, clinker, coal or other materials that are subject to rainfall runoff.

The raw materials for cement production include lime (calcium oxide), silica, aluminum, iron, and gypsum. Lime, the largest single ingredient, comes from cement rock, oyster shell marl, or chalk.

The wet process grinds up the raw materials with water and feeds them into the kiln as a slurry.

The dry process drys the raw materials, grinds and then feeds them into the kiln in a dry state.

In each of these processes, there are three major steps: grinding and blending, clinker production, and finish grinding. Clinker is a material about the size of large marbles that has been through the kiln but has not been fine-ground into finished cement.

The cement industry numbered 170 establishments in 1971 with the typical plant production estimated to be 520,000 kkg per year.

In 1973, 80.5 million metric tons were produced. From 1967 to 1973, production increased at a compound annual average rate of 5.3 percent. Imports have risen to meet demand, growing from 1.0 metric tons in 1967 to 6.1 million in 1973. Exports have increased to 454,000 metric tons in 1974.

Prices have increased due to higher production costs and pollution abatement costs. Fuel cost increases and the paper bag shortage are expected to affect prices.

Waste Sources and Pollutants. The main sources contributing to the total waste load come from the following: in-plant leakage, non-contact steam cooling water, process water, kiln dust piles runoff water, housekeeping, and wet scrubbers.

In order to define waste characteristics, the following basic parameters were used to develop guidelines for meeting BPT and BAT: pH, total dissolved solids, total suspended solids, alkalinity, potassium, sulfate, and temperature (heat).

BPT for plants in the non-leaching subcategory has been defined as no discharge of pollutants from manufacturing except for high temperature where an increase of 3°C is permitted.

For plants in the leaching subcategory, BPT is the same except for the dust-contact streams where reduction of pH to 9.0 and suspended solids to 0.4 kg/kkg of dust leached is required. For plants subject to the provisions of the Materials Storage Piles Runoff Subcategory, either the runoff should be contained to prevent discharge or the runoff should be treated to neutralize and reduce suspended solids.

BAT for both leaching and non-leaching plants is defined as no discharge of pollutants. For plants subject to the provisions of the Materials Storage Piles Runoff Subcategory, the definition of BPT is applied to BAT.

NSPS is the same as BPT except that no discharge is permitted for plants with materials storage pile runoff.

Control Technology and Costs. The main control and treatment methods for the cement industry involve recycle and reuse of wastewater. The devices employed include cooling towers or ponds, seizing ponds, containment ponds, and clarifiers.

For leaching plants, additional controls are needed to adequately control alkalinity, suspended solids, and dissolved solids. Alkalinity is controlled by neutralization, or carbonation; suspended solids by clarification, sometimes with the addition of flocculating agents. Although none of the leaching plants currently use a treatment method to control dissolved solids, several processes that might be employed include evaporation, precipitation, ion exchange, reverse osmosis, electrodialysis, and combinations of these.

In-plant control methods include good maintenance and operating procedures to minimize solid spillage and to return dry dust to the process. Solids introduced into storm water runoff can be minimized by paving areas for vehicular traffic, providing good ground cover in other open areas, and removing accumulations of dust from roofs and buildings, and by building ditches and dikes to control runoff from materials storage piles.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	$39.1
Incremental BPT O&M	$ 6.0

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. As can be noted, both estimates are within an acceptable range of computational variance. Some minor difference, however, may be attributed to model plant cost assumptions.

[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-30-1.
Cement
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (MT/Day)	80,605.	98,313.	101,915.
EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	34.27	43.15	45.38
Dissolved Solids	75.21	94.72	99.61
Bases	17.87	22.50	23.66
Legislated Controls:			
TSS	23.73	5.71	0
Dissolved Solids	58.42	14.95	0
Bases	9.98	2.06	0

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER		
Investment	1974-77	1978-83	1976-85
Existing Plants			
On-site Treatment	35.91 (BPT)	5.83 (BAT)	21.02
Pretreatment	0.00	0.00	0.00
New Plants	5.37	12.27	16.08
Municipal Investment Recovery	0.0	0.0	0.0
Totals	41.28	18.10	37.10

Table 4-30-1. (Continued)
Cement
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	5.43	7.81	8.08	65.66[2]
O&M[3]				
On-site Treatment	7.25	9.05	10.48	82.01
Pretreatment	0.0	0.0	0.0	0.0
Totals	7.25	9.05	10.48	82.01
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	12.68	16.85	18.55	147.67

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Cement industry includes the production of cement by the wet and dry or the materials storage run-off process.

INSULATION FIBERGLASS INDUSTRY

Production Characteristics and Capacities. The insulation fiberglass industry has no subcategories. The raw materials for fiberglass production are 55-73 percent silica and 27-45 percent fluxing oxides (e.g., limestone and borates) to manufacture the fiberglass filaments, and a phenolic resin to bind the filaments together. Four basic types of glass are used: low-alkali lime alumina borosilicate, soda-lime borosilicate, lime-free borosilicate, and soda-lime.

The basic process for fiberglass manufacture is as follows: the raw materials batch is melted to form a homogeneous glass stream (there are two ways that the melting process can be done: direct melting or marble process), then the molten glass stream is fiberized to form a random mat of fibers which are bonded together with a thermosetting phenolic binder or glue. The glass is fiberized in two ways: flame attenuation and rotary spinning. The trend in the industry is toward more use of direct melting and the rotary spinning fiber-forming process.

The primary domestic uses for insulation fiberglass are: insulating material, noise insulation products, air filters, and bulk wool products.

In 1972, there were 19 plants operated by three companies involved in fiberglass production. The typical plant produces 123,000 metric tons per year, and all plants contribute to wastewater discharge.

In 1972, total fiberglass production amounted to 0.77 million metric ton. Of the $427 million in annual sales, exports amounted to $8.4 million and imports were $0.7 million; therefore, foreign trade is not a significant portion of total consumption.

Waste Sources and Pollutants. The main sources contributing to total waste load are summarized in Table 4-31-1. In order to define waste characteristics, the following parameters were chosen to develop guidelines for meeting BPT and BAT:

- Phenols
- BOD_5
- COD
- Total Suspended Solids (TSS)
- pH

Table 4-31-1.
Insulation Fiberglass Industry Pollutant Sources

Waste Stream	Phenols	BOD5	COD	DS	SS	Oil & Grease	Amonia	pH	Color	Specific Turbidity	Temp.	Conductance
Air Scrubbing	X	X	X	X	X				X	X	X	X
Boiler Blowdown				X	X					X	X	X
Caustic Blowdown				X	X			X		X		
Chain Spray	X	X	X	X	X	X	X	X	X	X		X
Cullet Cooling				X	X						X	
Fresh Water Treatment				X	X			X		X	X	X
Hood Spray	X	X	X	X	X	X	X	X	X	X		X
Noncontact Cooling Water				X							X	X

Source: EPA Development Document, January 1974.

Control Technology and Costs. Because of the large volume of process waters and the reaction of the chain wash water to treatment and recycle, total recycling of wastewaters is the most economical treatment alternative for the insulation fiberglass industry. Sample recycling systems consist of coarse filtration, followed by either fine filtration or flocculation and settling.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	$15.0
Incremental BPT O&M	$ 2.6

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. As can be noted, both estimates are within an acceptable range of computational variance.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-31-2.
Insulation Fiberglass
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (Million kg/Yr)	912.	1,132.	,136.

Annual Growth Rate Over the Period 1976-1985 = 2.73%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	2.06	2.57	2.69
BOD_5	2.73	3.41	3.57
COD	11.60	14.49	15.16
Dissolved Solids	9.90	12.37	12.94
Legislated Controls:			
TSS	0.58	0	0
BOD_5	0.77	0	0
COD	3.27	0	0
Dissolved Solids	2.79	0	0

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER		
Investment	1974-77	1978-83	1976-85
Existing Plants			
On-site Treatment	16.14 (BPT)	11.49 (BAT)	18.63
Pretreatment	0.00	0.00	0.00
New Plants	1.92	6.00	6.65
Municipal Investment Recovery	0.0	0.0	0.0
Totals	18.06	17.49	25.28

Table 4-31-2. (Continued)
Insulation Fiberglass
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	2.37	4.67	4.70	34.86[2]
O&M[3]				
On-site Treatment	5.90	8.66	15.62	87.38
Pretreatment	0.0	0.0	0.0	0.0
Totals	5.90	8.66	15.62	87.38
Muncipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	8.28	13.34	20.31	122.24

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Insulation Fiberglass industry includes the production of insulating material, noise insulation processes, and bulk wool products.

FLAT GLASS INDUSTRY

Production Characteristics and Capacities. The flat glass industry may be divided into six major subcategories based on the processes employed. However, since the sheet and rolled glass manufacturing industries do not contribute a wastewater discharge, they will not be considered for the purposes of this report. The major division in the industry is between primary and automotive glass manufacturers and the processes they use. Automotive glass manufacture is a fabrication process using primary glass. The four industry subcategories covered in this study are: plate and float--primary glass production, and tempering and lamination--automotive glass production.

There were 47 establishments in the flat glass industry in 1972. Of these, it is estimated that 34 have waste process water. The plants that are contributing to effluent discharge produced 7,400 metric tons per day of primary glass and 172,700 square meters per day of automotive glass in 1972.

Glass is produced by combining the following raw materials: sand (silica), sodium carbonate, calcium carbonate, magnesium carbonate, and cullet (waste glass of which 25 percent can be reused). The float glass process is the major user of these materials.

In primary glass production, the following processes affect wastewater discharge: (1) washing, (2) batching, and (3) grinding and polishing. In the production of automotive glass, the following processes affect wastewater discharge: (1) seaming, (2) grinding, (3) drilling, (4) cooling, and (5) washing.

The batching process in primary glass manufacturing brings together the raw materials and mixes them to a homogeneous consistency.

The grinding and polishing process is used for plate, float, and tempered glass. This process uses either a single or twin configuration. (The twin configuration grinds and polishes simultaneously.) The grinding part of the process uses a slurry of sand and water which is continuously being blown down in order to be recycled and classified as a progressively finer grinding medium is needed. The polishing process uses a polishing surface of animal felt, and a polishing medium of water and iron oxide or cerium oxide slurry. The glass is reduced 15 percent by the combined grinding and polishing process.

The washing process is used for plate glass to remove the slurry, and in float glass to remove the protective chemicals coated on the rollers which prevents the glass from getting marked.

The cooling process utilizes water for cooling in all the melting tanks, the float tanks, and bathing tanks. Water for cooling is also used on rollers for plate glass, to cool the annealing lehr, bending the lehr and in the tempering process.

The seaming and drilling processes in automotive glass manufacture are basic fabrication processes that aid in handling and meeting product specifications.

The tempering process includes heating and then rapidly cooling the glass.

Primary glass is used for all architectural and building requirements and is the basic component for fabricated flat glass products. Automotive glass is used primarily for windshields and safety glass.

In 1972, a total of 222 million square meters of primary glass and 77 million square meters of automotive glass was produced. It is estimated that plants contributing wastewater produced 7,400 metric tons per day of primary glass and 172,700 square meters per day of automotive glass.

The number of flat glass plants has increased in recent years but plate glass plants have decreased due to the greater profitability of the float glass process; U. S. flat glass exports are not significant. There has been a gradual increase in the amounts of imports, with imports comprising about 21 percent of total consumption. The demand for tinted or colored glass for reflective architectural uses and for tempered glass for safety applications in buildings is expected to grow. It should be noted, however, that the consumption of flat glass moves with the level of residential construction and automobile manufacturing.

Waste Sources and Pollutants. The major glass manufacturing wastes include: sand, silt, clay, grease, oil, tar, animal and vegetable fats, fibers, sawdust, hair sewage materials, phosphorus, alkaline flow (affecting pH) from plate glass manufacturing and thermal pollution (4.7° C over ambient temperature).

The main sources contributing to the total waste load come from the following processes in each segment of the industry: Float--washing; Plate--batching, grinding and polishing, and washing; Tempered--seaming, grinding drilling, cooling and washing (wash-water is the major source); and Laminated--cooling, seaming, and washing.

In order to define waste characteristics, the following parameters were used to develop effluent guidelines for meeting BPT and BAT: total suspended solids, oil, pH, and total phosphorus.

Effluent limitations and standards of performance for new sources are no discharge for the sheet plate glass manufacturing subcategory and best available control technology for the three remaining subcategories.

At the present time, the waste from about 70 percent of the industry is discharged to municipal sewage systems, and 20-30 percent of the wet process flat glass manufacturers discharge to municipal sewers. The typical discharge for each segment is as follows: Float-138 liters per metric ton; Plate-45,900 liters per metric ton; Tempered-49 liters per square meter: and Laminated-175 liters per square meter.

Control Technology and Costs. Waste treatment practices vary in each segment of the flat glass industry. Some use a lagoon system with a polyelectrolyte or partial recycling of process water. Others use no treatment or have only eliminated detergent in the wash water. Control methods include: filtration, filtration and recycle, total recycle with a reverse osmosis unit, coagulation sedimentation, a two-stage lagoon with mixing tank for proper polyelectrolytic dispersion, an oil absorbing diatomaceous earth filter and sludge dewatering by centrifugation.

The guidelines for BPT call for control and removal of total suspended solids (TSS), oil, pH, and total phosphorus. BPT calls for the following control methods for each segment of the industry:

- Plate. Two-stage lagoon with a mixing tank for proper polyelectrolytic dispersion.
- Float. Cream separator type centrifuge for sludge dewatering, and elimination of detergent use.
- Tempered and Laminated. Coagulation/sedimentation.

The BAT assesses the availability of in-process controls, as well as calling for additional treatment techniques. The following additional treatment methods for each segment of the industry are:

- Plate. Add a return of filter backwash to lagoon systems.
- Float. Eliminate all detergent use and add oil absorptive diatomaceous earth filtration.
- Tempered. Add oil absorptive diatomaceous earth filtration.
- Laminated. Recycle post-lamination washing and initial hot water rinse, gravity separation of remaining rinse waters, reduce detergent usage and add oil absorptive diatomaceous earth filtration.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

Incremental BPT Investment	$2.5
Incremental BPT O&M	$0.6

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. Principal reasons for differences between these cost estimates and the newer data are that these were changes in plant inventory estimates and that G&P considers plate glass plants and tempering and lamination of auto glass, whereas SEAS includes float glass but not plate glass.

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[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972", National Bureau of Economic Research, December, 1975. (Revised January, 1976)

Table 4-32-1.
Flat Glass
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (SQM/Day)	213,313.	279,930.	286,770.

Annual Growth Rate Over the Period 1976-1985 = 4.14%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	1.51	1.94	2.03
BOD5 (Flat Glass only)	0.72	0.92	0.97
COD	34.22	43.89	46.10
Oils and Greases	34.08	43.71	45.92
Legislated Controls:			
TSS	0.87	0.34	0.12
BOD5 (Flat Glass only)	0.40	0.46	0.47
COD	5.55	0.46	0.47
Oils and Greases	5.55	0.11	0.08

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	4.67	(BPT)	3.47	(BAT)	5.81
Pretreatment	1.50		0.00		0.00
New Plants	0.07		0.58		0.63
Municipal Investment Recovery	0.00		0.00		0.00
Totals	6.24		4.05		6.44

Table 4-32-1. (Continued)
Flat Glass
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR 1977	1983	1985	1976-85
Annualized Costs				
Annualized Capital[1]	0.75	1.29	1.29	9.89[2]
O&M[3]				
On-site Treatment	0.36	0.51	0.70	4.79
Pretreatment	0.19	0.16	0.13	1.71
Totals	0.54	0.66	0.84	6.50
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	1.30	1.95	2.13	16.39

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Flat Glass industry includes tempered and laminated processing.

PRESSED AND BLOWN GLASS INDUSTRY

Production Characteristics and Capacities. The effluent limitations guidelines for the pressed and blown glass manufacturing industry cover manufacturers of glass containers for commercial packing, bottling, home canning, and the manufacturers of glass and glassware, which is pressed, blown, or shaped from glass produced in the same establishment.

The industry has been divided into the following subcategories, based upon differences in production processes and wastewater characteristics:

- Glass containers
- Machine-pressed and blown glass
- Glass tubing
- Television picture tube envelopes
- Incandescent lamp envelopes-forming and frosting
- Hand-pressed and blown glass-leaded and hydrofluroic acid finishing, non-leaded and hydrofluoric acid finishing, and non-hydrofluoric acid finishing.

Four manufacturing steps are common to the entire pressed and blown glass industry: weighing and mixing of raw materials, melting of raw materials, forming of molten glass, and annealing of formed glass products. Further processing (finishing) is required for some products, especially television tube envelopes, incandescent lamp envelopes, and hand-pressed and blown glass.

Sand (silica) is the major ingredient of glass and accounts for about 70 percent of the raw materials batch. Other ingredients may include soda or soda ash (13-16 percent), potash, lime, lead oxide, boric oxide, alumina, magnesia, and iron or other coloring agents. The usual batch also contains between 10 and 50 percent waste glass (cullet).

Melting is done in three types of units: continuous furnaces, clay pots, or day tanks. Methods used to form glass include blowing, pressing, drawing, and casting. After the glass is formed, annealing is required to relieve strains that might weaken the glass or cause it to fail. The entire piece of glass is brought to a uniform temperature that is high enough to permit the release of internal stresses, and then it is cooled at a uniform rate to prevent new strains from developing; finishing steps include abrasive polishing, acid polishing, spraying with frosting solutions, grinding, cutting, acid etching, and glazing.

In 1972, approximately 300 plants manufactured pressed and blown glass products in the United States, and almost half of these manufactured glass containers. The glass container industry is relatively concentrated with the eight largest firms producing about 80 percent of the industry's shipments and operating about two-thirds of the individual plants. Because of the special nature of their products, the machine-pressed and blown glass industry is also relatively concentrated; as are the tubing, television picture tube envelope, and incandescent lamp envelope industries. On the other hand, the hand-pressed and blown glass industry is characterized by a large number of family-owned and-operated, single-plant companies. Of the 46 firms in this industry, only four operate more than one plant.

Waste Sources and Pollutants. Water is used in the pressed and blown glass manufacturing industry for non-contact cooling, cullet quenching, and product rinsing following the various finishing operations. Water may also be added to the raw materials batches for dust suppression. Wet fume scrubbers used in acid polishing areas also contribute wastewater discharge.

For the purposes of establishing effluent limitations guidelines, the following pollution parameters have been designated as significant: fluoride, ammonia, lead, oil, chemical oxygen demand(COD), suspended solids(SS), dissolved solids, temperature(heat), and pH. These parameters are not present in the wastewater from every subcategory, and may be more significant in one subcategory than in another. Wastewaters from non-contact cooling, boilers, and water treatment are not considered process wastewaters and are not covered by the guidelines.

Control Technology and Costs. The pressed and blown glass industry is currently treating its wastewaters to reduce or eliminate most of the pollutants. Oil is reduced by using gravity separators. Treating for fluoride and lead involves adding lime, rapid mixing, flocculation, and sedimentation of the resulting reaction products. Several glass container plants recycle non-contact cooling and cullet quench water. Treatment for ammonia removal is presently not practiced in the industry.

Additional treatment systems that are applicable to the industry include chemical or physical methods to further reduce oil levels, such as high-rate filtration, diatomaceous earth filtration, and chemical addition or coagulation; additional treatment of fluorides by ion-exchange or activated alumina filtration; and ammonia removal by stream or air stripping, selective ion exchange, nitrification/denitrification, or break-point chlorination.

Because current treatment practices in the pressed and blown glass industry provide wastewater pollutant concentrations that are already at low levels, no additional control technologies are proposed for most subcategories to meet BPT guidelines. The major exception is the addition of steam stripping to control ammonia discharges from the incandescent lamp envelope manufacturing subcategory.

Additional technologies required for BAT and NSPS guidelines include segregation of non-contact cooling water from the cullet quench water, recycling cullet quench water, treatment of cullet quench water blowdown by dissolved air flotation and diatomaceous earth filtration, and treatment of finishing wastewaters by sand filtration and activated alumina filtration.

Table 4-33-1 summarizes the control technologies recommended for each subcategory; as indicated, most of the plants in the pressed and blown glass industry already have sufficient operating technology to meet BPT guidelines. In addition, as shown in Table 4-33-1, only about one-third of the approximately 300 plants covered by these guidelines discharge to surface waters. The remaining plants either have no discharge or, as in most cases, they discharge to municipal systems.

All annualized costs are detailed in Table 4-33-2.

Table 4-33-1.
Pressed and Blown Glass
Industry Pollution Control Technologies

Subcategories	BPT	BAT
Glass Containers	Housekeeping	Recycle, gravity oil separation and filtration
Machine-pressed & blown glass	Housekeeping	Recycle, gravity oil separation and filtration
Glass tubing	Housekeeping	Cooling tower and filtration
TV tube envelopes	Lime addition, coagulation, and sedimentation	Sand filtration, activated alumina filtration
Incandescent lamp envelopes	Steam stripping, lime precipitation and recarbonization	Sand filtration, activated alumina filtration
Hand-pressed & blown glass	Batch lime precipitation, coagulation, sedimentation	Sand filtration, activated alumina filtration

NSPS are the same as BAT for all subcategories.

Table 4-33-2.
Pressed & Blown Glass
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (kkg/Day)	75,644.	109,240.	116,170.

Annual Growth Rate Over the Period 1976-1985 = 6.14%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985

Note: Residual data not available at time of Report issue.

1971 Controls:

Legislated Controls:

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	4.70	(BPT)	44.32	(BAT)	46.58
Pretreatment	0.00		0.00		0.00
New Plants	2.26		20.74		24.10
Municipal Investment Recovery	8.69		108.59		157.90
Totals	15.66		173.65		228.59

Table 4-33-2. (Continued)
Pressed & Blown Glass
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	0.92	9.47	9.84	53.12[2]
O&M[3]				
On-site Treatment	0.60	1.73	6.22	20.71
Pretreatment	0.0	0.0	0.0	0.0
Totals	0.60	1.73	6.22	20.71
Municipal Charges				
Investment Recovery	4.72	20.61	21.09	157.90
User Charges[4]	10.62	22.55	23.73	256.84
Totals	15.34	43.16	44.82	414.74
Grand Totals	16.86	54.36	60.88	488.57

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Pressed and Blown Glass industry includes the production of T/V tubes, tubing, containers, incadescent bulbs, machine-pressed processing, and hand-pressed processing.

ELECTROPLATING

Production Characteristics and Capacities. The electroplating industry is a subcategory of the metal finishing industry and includes establishments engaged in applying metallic coatings on surfaces by electrode position. These coatings provide corrosion protection, wear or erosion resistance, antifrictional characteristics, lubricity, electrical conductivity, heat and light reflectivity, or other special surface characteristics.

This analysis covers the Phase I guidelines for the electroplating of copper, nickel, chromium, and zinc on ferrous, nonferrous, and plastic materials. Phase II regulations, which cover the additional metal-finishing operations of anodizing, buffing, and polishing, were promulgated too late for inclusion in this report.

An electroplating process involves cleaning, electroplating, rinsing, and drying. The cleaning operation comprises two or more steps, usually sequential treatments in an alkaline solution and an acid solution, to remove grease, oil, soil, and oxide films from the basic metal surfaces to insure good adhesion. In the electroplating operation, metal ions in either acid, alkaline, or neutral solutions are reduced on the work pieces being plated, which serve as cathodes. Hundreds of different electroplating solutions have been adopted commercially, but only two or three types are utilized widely for a single metal or alloy. For example, cyanide solutions are popular for copper, zinc, and cadmium. Acid sulfate solutions and non-cyanide alkaline solutions containing pyrophosphate or another chelating agent are also used. The parts to be plated are usually immersed in the electroplating solutions upon racks, although small parts are allowed to tumble freely in open barrels.

Mechanized systems have been developed for transferring both barrels and racks from cleaning, plating, and rinsing tanks. In some instances, dwell time and transfer periods are programmed on magnetic tape or cards for complete automation.

Approximately 20,000 companies are engaged in metal finishing activities. In over 85 percent of these companies, metal finishing is merely one step in a manufacturing process. Because these "captive shop" operations are not classified, it is extremely difficult to obtain good information on most of the U.S. metal platers.

Hence, this analysis addresses only independent (non-captive) electroplating facilities.

Electroplating facilities vary greatly in size and character. Over 70 percent of the shops have fewer than 20 employees, while the largest shops have more than 150 employees. The area of the products being electroplated varies from less than 10 to more than 1,000 square meters per day. Products being plated vary in weight from less than 30 grams to more than 9,000 kilograms. Most of the plants perform specialized batch operations, but in some plant operations, continuous strip and wire are plated on a 24-hour per day basis. Some companies have capabilities for electroplating 10 or 12 different metals and alloys; others specialize in just one or two.

Waste Sources and Pollutants. Water is used in electroplating operations to accomplish the following tasks:

- Rinsing of parts, racks, and equipment
- Washing equipment and washing away spills
- Washing the air in ventilation ducts
- Dumps of operating solutions
- Cooling water to cool solutions (usually reused for rinsing).

Approximately 90 percent of the water is used in rinsing operations; this water is used to rinse away the films of processing solutions from the surface of the work pieces. In performing this task, the water is contaminated by the operating solutions and is not directly reusable.

In electroplating facilities, the wastes are derived principally from the material plated and the operating solutions. The most important wastes are made potentially toxic by the formation of heavy metal salts and cyanide salts.

For the purpose of establishing effluent limitations guidelines for copper, nickel, chromium, and zinc plating operations, the major wastewater constituents of polluting significance have been defined to be: copper, nickel, hexavelent chromium, total chromium, zinc, cyanide which is amenable to oxidation by chlorine, total cyanide, suspended solids (SS), and pH. Other wastewater constituents of secondary importance that are not the subject of the guidelines include: total dissolved solids, chemical oxygen demand, biochemical oxygen demand, oil and grease, turbidity, color and temperature.

Control Technology and Costs. Pollution control and wastewater treatment technologies for reducing the discharge of pollutants from copper, nickel, chromium, and zinc electroplating processes include both in-plant controls and end-of-process treatment system. The most commonly-used treatment in the electroplating industry is the chemical method. The rinse waters are usually segregated into these three streams prior to treatment:

- Those containing hexavalent chromium,
- Those containing cyanide, and
- The remainder containing water from acid dips, ackali cleaners, acid copper, nickel, and zinc baths, etc.

The cyanide is oxidized by chlorine, and the hexavalent chromium is reduced to trivalent chromium with sulfur dioxide or other reducing agents. The three streams are then combined, and the metal hydroxides are precipitated by adjusting the pH through chemical addition. The hydroxides are allowed to settle out, often with the help of coagulating agents, and the sludge is hauled to a lagoon or filtered and used as land fill. These chemical facilities may be engineered for batch or continuous operations.

Water conservation can be accomplished by: in-plant process modifications and materials substitutions requiring little capital or new equipment (substituting low concentration electroplating solutions for high concentration baths or the use of noncyanide solutions); good housekeeping practices; reducing the amount of rinse water lost when parts are removed from the solution; and reducing the volume of rinse water used by installing counterflow rinses, adding wetting agents, and installing air or ultrasonic agitation. Significant amounts of water can also be conserved by using advanced treatment methods, such as ion exchange, evaporative recovery, or reverse osmosis to treat and recycle in-process waters. Other more experimental in-process treatment methods include freezing, electrodialysis, ion-flotation, and electrolytic stripping. One system currently in operation has achieved zero discharge of pollutants through the use of reverse osmosis followed by evaporation and distillation of the concentrated waste stream from the reverse osmosis unit.

BPT for the electroplating industry is based upon the use of chemical methods of treatment of the wastewater at the end of the process controls to conserve rinse water and reduce the amount of treated water discharged. NSPS are based upon the above technology plus the utilization of the best multi-tank rinsing practices after each process. Maximum use of combinations of evaporative, reverse osmosis, and ion exchange systems for in-process control are also recommended. BAT is the use of in-process and end-of-process control and treatment to achieve no discharge of pollutants.

An informal survey suggests that substantial amounts of waste treatment equipment are currently installed in metal finishing plants. These data indicate that most electroplating establishments have at least some of the BPT equipment already in place. Some of this will have to be upgraded to satisfy BPT requirements, but a total investment in new technology will not be necessary. In addition, the majority of electroplaters discharge their wastewaters to municipal sewage systems.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The G&P estimates are as follows (in million 1975 dollars):

	Total	Phase I	Phase II
Incremental BPT Investment	1,994.1	1,794.1	200.
Direct Discharging	516.6	470.6	46.1
Pretreating	1,447.5	1,323.5	154.0
Incremental BPT O&M	856.5	816.3	40.3
Direct Discharging	223.6	215.2	8.4
Pretreating	633.0	601.1	31.9

Estimates from the earlier SEAS calculation are presented below, with projected pollutant discharges associated with these costs. SEAS addressed only those costs associated with Phase I production. As noted in the industry description, SEAS addresses only independent electroplating facilities, and does not calculate costs for captive shops, as does G&P. Growth rate assumptions also affect the forecasts.

[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972," National Bureau of Economic Research, December 1975. (Revised January 1976)

Table 4-34-1.
Electroplating
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (MT/Yr)	365,491.	481,173.	506,233.

Annual Growth Rate Over the Period 1976-1985 = 3.78%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
Dissolved Solids	155.84	207.25	220.13
Nutrients	3.19	4.24	4.50
Acids	16.52	21.97	23.33
Legislated Controls:			
Dissolved Solids	107.53	25.20	0
Nutrients	1.01	0.04	0
Acids	4.79	0.06	0

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	359.87	(BPT)	1,018.22	(BAT)	1,189.18
Pretreatment	381.23		0.00		0.00
New Plants	816.25		1,367.16		1,676.96
Municipal Investment Recovery	53.79		407.16		600.06
Totals	1,611.15		2,792.54		3,466.20

Table 4-34-1. (Continued)
Electroplating
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	186.77	500.39	530.50	3,612.56[2]
O&M[3]				
On-site Treatment	27.90	72.45	295.67	946.31
Pretreatment	115.22	271.93	362.71	2,119.82
Totals	143.12	344.39	658.38	3,066.13
Municipal Charges				
Investment Recovery	23.53	75.63	76.97	600.06
User Charges[4]	37.99	63.68	64.99	798.81
Totals	61.52	139.31	141.96	1,398.88
Grand Totals	391.42	984.09	1,330.84	8,077.57

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Electroplating industry includes job shop operations that apply metallic coatings to material surfaces.

STEAM ELECTRIC POWER INDUSTRY

Production Characteristics and Capacities. The electric utility industry is composed of three types of companies: those owned by investors, those owned by the public (Federal, state or local governments), and those owned by cooperatives. Companies owned by the public or by cooperatives are engaged primarily in the distribution of electricity; companies owned by investors are engaged in generation, transmission, and distribution.

The 500 investor-owned companies serve fewer separate electrical systems than cooperatives or publically-owned companies, but they account for most of the generating capacity and generate most of the electricity. In 1973, investor-owned companies had 78 percent of the generating capacity; publically-owned companies had 20 percent, and cooperatives had 2 percent.

The steam electric power industry has been divided into three sub-categories according to size and age of generating plants, and a fourth based on area; a summary of the subcategories follows:

Subcategory	Generation Capacity (megawatts)	Date Initial Operation[1]
Generating Unit	> 25	After 1/1/74
	>500	After 1/1/70
Small Unit	< 25	
Old Unit	>500	On or before 1/1/70
	<500	On or before 1/1/74
Area Runoff	All Sizes	

[1] Final effluent guidelines were issued on October 8, 1974, in the Federal Register (39FR36186). These guidelines exempt all units placed into service before 1970 from meeting limitations on the discharge of heat.

The generating capacity of the industry may be further classified by the type of fuel employed to drive the generator. As shown in Table 4-35-1, coal is the predominant fuel used. In recent years, there has been a shift from coal to oil, principally because state and local environmental restrictions required the use of low sulfur fuels, a requirement more easily met by oil then coal. More recently, the increasing prices of foreign crude oil have caused a reversal of this trend as utilities return to lower priced coal as their fuel.

Waste Sources and Pollutants. The major waste product from electric power generation is heat. Depending on the type of fuel consumed, substantial quantities of metal cleaning wastes, water treatment wastes, miscellaneous housekeeping wastes, bottom ash and fly ash may also be produced. Waste cooling water may contain corrosion inhibitors and biocides, principally chlorine.

The main sources contributing to the total waste load come from both power generation and housekeeping: cooling water and cooling water blowdown, boiler blowdown, metal cleaning wastes, ash transport water, low volume wastes, and construction and storage runoff.

In order to define waste characteristics, the following parameters were used to develop guidelines for meeting BPT and BAT: (1) total suspended solids, (2) oil and grease, (3) free available chlorine, (4) total copper, (5) total iron, (6) zinc, (7) chromium, (8) phosphorous, (9) other corrosion inhibitors, (10) polychlorobiphenyls (PCB), (11) pH, and (12) heat.

Specific waste loads have not been characterized, but they may be expected to vary with the type of fuel:

- Coal burning plants produce the heaviest burden of wastes because of the large amounts of fly ash and bottom ash produced. Pollutants are caused by runoff from coal storage areas, boiler blowdown, metal cleaning wastes, once-through cooling water or cooling water blowdown, and low volume wastes, including wet scrubber wastes, water treatment wastes, laboratory and sampling wastes, and housekeeping wastes, such as pump seal oil.

- Oil burning plants generate no bottom ash and much less fly ash than coal burning plants. Otherwise, the wastes are about the same except that there are substantial quantities of oily water from oil use and storage, but no runoff from coal storage.

- Gas burning plants produce almost no ash and require no air pollution equipment for control of particulates and sulfur dioxide. Otherwise, the wastes are the same as for coal and oil except that there is no waste stream

Table 4-35-1.
Steam Electric Power Industry Structure

Size (megawatt)	Coal		Oil		Gas		Nuclear		Total	
	No. Plants	Total Cap. (%)	No. Plants	Total Cap. (%)	No. Plants	Total Cap. (%)	No. Plants	Total Cap. (%)	No. Plants	Total Cap. (%)
< 25	213	14.0	60	5.0	115	8.0	3	0.2	391	27.2
25-500	537	11.0	151	4.0	101	0.1	15	1.0	804	16.1
> 500	173	37.5	49	11.2	2	7.1	15	1.1	239	56.9
Totals	923	62.5	260	20.2	218	15.2	33	2.3	1434	100.2[1]

[1] Percentages do not add to 100 because of rounding.

Source: EPA Development Document.

associated with fuel storage, and none associated with maintenance cleaning of the stack.

- Nuclear plants produce no ash or fuel storage waste streams, and metal cleaning wastes are limited to the cooling tower basin and generator tubes. Otherwise, the wastewaters are similar to those of fossil fuel plants. Radioactive wastes are not covered in effluent guidelines.

Control Technology and Costs. Wastewater treatment generally has not been practiced in the steam electric power industry; however, based on assumptions concerning the nature of the wastestreams, the treatment technology is readily projected.

- Cooling Water. Where unlimited discharge of heated water is permitted, there is no requirement for treatment. Where recirculating cooling water systems are in use, it will be necessary to remove corrosion inhibitors from the blowdown to meet 1983 criteria. This can be achieved by treatment with sulfur dioxide to reduce hexavalent chromium followed by chemical precipitation of heavy metals and phosphate, and filtration. Since new source performance standards permit no discharge of corrosion inhibitors, it will be necessary to construct cooling facilities of corrosion-inhibiting materials.

- Metal Cleaning Wastes and Boiler Blowdown. Metal cleaning wastes are generated on an intermittent basis. Treatment of this stream, as well as the boiler blowdown stream, can be achieved by equalization, chemical precipitation of heavy metals, and filtration. Where chemical treatment of cooling waters blowdown is necessary, these streams can be combined for treatment.

- Ash Transport Water and Low Volume Wastes. The blowdown from recirculating ash transport water can be treated to meet all standards by neutralization, oil separation, and clarification. Where discharge of pollutants from fly ash transport is prohibited, it will be necessary to resort to dry removal methods. Low volume wastes are treated by equalization, neutralization, oil separation, and clarification. They may be combined with the blowdown from ash transport water for treatment.

- Area Runoff. Area runoff may be treated by impoundment, lime addition for pH control, and discharge of the neutral, settled water.

The most recent analysis of costs for this sector was provided to the Agency by Temple, Barker & Sloane, Inc., (TBS)[1]. This analysis was conducted in somewhat greater depth than, and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure, and is considered to be more precise. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The TBS estimates are as follows (in million 1975 dollars):•

Incremental Investment (1974-1983)	4,500
Incremental O&M (1974-1983)	2,100

Estimates from the earlier SEAS calculations are presented in Table 4-35-1 (with capital expenditures during the period 1974-1983 equal to 5.2 billion dollars). The SEAS values were based upon the EPA report Economic Analysis of Efficient Guidelines, Steam Electric Plants (December 1974). Costs for enhancement were not estimated in this earlier report, and thus are not included in the SEAS projections. Two significant modifications are included in the revised baseline estimates for the electric utility industry. First, capital expenditures requirements have declined primarily because reduced growth for the industry means fewer new units will be built than had previously been expected. The O&M costs have risen due to the increased fuel costs acclerating the cost of making up the energy penalties associated with closed-cycle cooling. The net change from the results associated with the 1974 report has been approximately a seventeen percent reduction in kilowatts covered by the relatively expensive thermal guidelines, a twelve percent reduction in capital expenditure impacts and a substantial increase in operations and maintenance expenses.

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[1] "Economic and Financial Impacts of EPA's Air and Water Pollution Controls on the Electric Utility Industry," Temple, Barker & Sloane, Inc., May 1976.

Table 4-35-2.
Steam Electric Power
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (Megawatts)	726,560.	1,120,300.	1,267,000.

Annual Growth Rate Over the Period 1976-1985 = 7.62%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS (Coal only)	80.61	89.35	93.73
Dissolved Solids (Coal and Elec. Utilities)	2,724.21	3,043.00	3,201.58
Legislated Controls:			
TSS (Coal only)	65.35	16.39	0
Dissolved Solids (Coal and Elec. Utilities)	2,832.02	3,155.48	3,322.16

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	1,018.50	(BPT)	157.13	(BAT)	698.23
Pretreatment	0.00		0.00		0.00
New Plants	1,608.16		2,453.46		4,674.41
Municipal Investment Recovery	0.0		0.0		0.0
Totals	2,626.67		2,610.60		5,372.64

Table 4-35-2. (Continued)
Steam Electric Power
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	345.34	670.92	788.53	5,346.65[2]
O&M[3]				
On-site Treatment	131.88	253.57	331.04	2,108.53
Pretreatment	0.0	0.0	0.0	0.0
Totals	131.88	253.57	331.04	2,108.53
Municipal Charges				
Investment Recovery	0.0	0.0	0.0	0.0
User Charges[4]	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Grand Totals	477.22	924.49	1,119.57	7,455.18

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Steam Electric industry includes power generation using coal, oil, natural gas, and nuclear fuels.

SOAP AND DETERGENT INDUSTRY

Production Characteristics and Capacities. Data from the Census of Manufacturers, 1967, identify 668 establishments in the industry. In spite of this large number, production is highly-concentrated in the industry with 12 establishments accounting for 47 percent of the industry's value-added, and 28 establishments accounting for 73 percent of value-added. The "big three" companies, Proctor and Gamble, Lever Brothers, and Colgate-Palmolive, dominate the package detergent industry with 80-85 percent of the market.

The soap and detergent industry establishments are engaged in the manufacture of soap, synthetic organic detergents, inorganic alkaline detergents, or any combination of these processes. Crude and refined glycerine production from vegetable and animal fats and oils is also accomplished by firms in the industry. In popular use, the term "soap" refers to those cleaning agents based primarily on natural fat. The term "detergent" is generally restricted to cleaning compounds derived largely from petrochemicals. Detergents can be formulated with entirely different organic and inorganic chemicals to exhibit the same cleaning power or have the same biodegradability.

Basic raw materials used in the manufacture of soap come from chemical and agricultural processors and include caustic soap, fats, and oils. Raw materials for detergents are supplied mostly from large chemical and petrochemical companies and consist primarily of detergent alkylate, alcohols, and surfactants.

Soaps and detergents are produced with a variety of manufacturing processes. In the traditional batch-kettle process of manufacturing soap, a mixture of refined and bleached fats, oils, caustic soda, and salt is alternatively boiled, settled, and drained of lye, etc., over a period from 4 to 6 days. Another process first converts the fats and oils to fatty acids, then mixes these with caustic soda, soda ash, and salt to produce soap; this "fatty acid neutralization" process is faster and produces less wastewater.

Detergents customarily consist of two main components, the surfactant or active ingredient, and the builder which performs many functions including buffering the pH and soil dispersion. Surfactants, usually alcohol sulfate or alkyl benzene sulfonate, are produced from a variety of processes in which alcohols, alkyl benzene and/or ethoxylates are combined in a reactor with sulfur compounds, usually sulfur trioxide. The resultant products are then neutralized and blended with the requisite builders and additives to produce the desired detergent.

Waste Sources and Pollutants. Waste loads from the different soap and detergent manufacturing processes vary considerably. Some processes are completely dry and produce no wastewaters. The major pollution sources from other processes are leaks and spills, washout waters, scrubber water from air pollution control equipment, barometric condensate, and cooling tower blowdown. Wash and wastewaters produced by some of the processes result in some very strong pollutants, such as sewer lyes, salt brine, acids, glycerine foots, and spent catalysts.

Pollutants covered by the effluent limitations guidelines include BOD_5, COD, suspended solids, surfactants, oil and grease, and pH.

Control Technology and Costs. Almost all (98 percent) of the plants in the soap and detergent industry discharge their wastewater into municipal treatment systems. This leaves fewer than a dozen plants which are point-source dischargers into navigable waters. Of these, only one has a complete primary-secondary treatment system. Several plants have aerated or non-aerated lagoons.

The major pollutants and the treatment methods usually employed to handle them are as follows:

Pollutants	Treatments
Oil and grease	1. Gravity separation 2. Coagulation and sedimentation 3. Carbon absorption 4. Mixed-media filtration 5. Flotation
Suspended solids	1. Plain sedimentation 2. Coagulation and sedimentation 3. Mixed-media filtration
Dispersed organics	1. Bioconversion (i.e., aerated lagoons, extended aeration, activated sludge, contact stabilization, trickling filters) 2. Carbon absorption
Dissolved solids (inorganic)	1. Reverse osmosis 2. Ion exchange 3. Sedimentation 4. Evaporation
Acidity or alkalinity	1. Neutralization
Sludge disposal	1. Digestion 2. Incineration 3. Lagooning 4. Thickening 5. Centrifuging 6. Wet oxidation 7. Vacuum filtration

Source: EPA Development Document, April 1974, p.96.

Probably the largest reductions in the pollution load from this industry can be made through lower process water usage. One of the biggest improvements would be either changing the operating techniques associated with the barometric condensers or replacing them entirely with surface condensers. Large reductions in water usage in the manufacture of liquid detergents could be achieved through the installation of additional water recycling, and by the use of air rather than water to blow out filling lines.

BPT guidelines call for plants to adopt good housekeeping procedures, adopt recycling where appropriate, and install biological secondary treatment (bioconversion). BAT guidelines assume improvement in manufacturing processes such as the replacement of barometric condensers by surface condensers, the installation of tandem-chilled water scrubbers (for spray-dried detergents), and the use of a batch counter-current process in air-SO_3 sulfation and sulfonation. In addition, improvements in end-of-pipe treatment are expected including the addition of sand or mixed-media filtration or the installation of a two-stage, activated sludge process. New source performance standards are the same as BAT for most product subcategories. Improvements over BAT are expected where the installation of new, lower-polluting processes, such as continuous processes instead of batch processes, is possible.

Since approximately 90 percent of the soap and detergent manufacturers discharge into municipal sewers, the total cost to the industry of meeting these guidelines is low. Annualized control costs and industry statistics are detailed in Table 4-36-1.

A recent analysis of costs for this sector was conducted by Gianessi and Peskin (G&P)[1]. This study was conducted independently and subsequent to the general data gathering efforts associated with the SEAS uniform cost calculation procedure. However, time and resource constraints prevented incorporating these costs into the scenario analyses using the SEAS model procedure. The soap and detergent G&P estimates are as follows (in 1975 dollars):

Incremental BPT Investment	7.0
Incremental BPT O&M	1.1

Estimates from the earlier SEAS calculations are presented below, with projected pollutant discharges associated with these costs. The principal reason for the difference in the estimates is that G&P assumes that 95 percent of total process water flow is discharged to municipalities, and that 77 percent of the plants incur pretreatment costs, being detergent plants. SEAS assumes no pretreatment costs, the only costs to the industry being municipal charges. There is also a substantial difference in growth assumptions about the industry. The municipal charges listed by G&P for soaps and detergents is 24.7 million dollars, as compared to the SEAS estimate for Municipal Investment Recovery and User Charges, summing to 28.0 million dollars over a comparable period.

[1] Gianessi, L. P. and H. M. Peskin, "The Cost to Industries of the Water Pollution Control Amendment of 1972," National Bureau of Economic Research, December, 1975. (Revised January 1976)

Table 4-36-1.
Soap and Detergent
Industry Data Summary

ACTIVITY LEVEL	1977	1983	1985
Capacity (KKG/Day)	2,773.	4,469.	4,865.

Annual Growth Rate Over the Period 1976-1985 = 7.16%

EFFLUENTS (1,000 MT/Yr)	1977	1983	1985
1971 Controls:			
TSS	5.54	8.56	9.32
BOD5	16.51	25.53	27.80
COD	12.97	20.06	21.84
Oils and Greases	0.58	0.89	0.97
Legislated Controls:			
TSS	2.14	1.55	1.68
BOD5	6.38	2.54	2.01
COD	6.08	3.17	2.48
Oils and Greases	0.22	0.16	0.18

CONTROL COSTS (Million 1975 $)	AGGREGATED OVER				
Investment	1974-77		1978-83		1976-85
Existing Plants					
On-site Treatment	0.0	(BPT)	0.0	(BAT)	0.0
Pretreatment	0.0		0.0		0.0
New Plants	0.0		0.0		0.0
Municipal Investment Recovery	8.89		68.99		101.74
Totals	8.89		68.99		101.74

Table 4-36-1.
Soap and Detergent
Industry Data Summary

CONTROL COSTS (Million 1975 $) - (Continued)	COST IN YEAR			
Annualized Costs	1977	1983	1985	1976-85
Annualized Capital[1]	0.0	0.0	0.0	0.0[2]
O&M[3]				
On-site Treatment	0.0	0.0	0.0	0.0
Pretreatment	0.0	0.0	0.0	0.0
Totals	0.0	0.0	0.0	0.0
Municipal Charges				
Investment Recovery	3.88	12.91	13.19	101.74
User Charges[4]	6.36	12.85	13.76	146.92
Totals	10.24	25.76	26.94	248.66
Grand Totals	10.24	25.76	26.94	248.66

[1] Annualized on-site and pretreatment costs are computed on the assumption of a 15 year useful life at 10 percent interest with zero salvage value.

[2] The decade total of annualized cost may not be relatable to the decade total of investment because of the timing of investment expenditures over the decade.

[3] O&M costs in any year are relative to investment made in the year plus all prior year investments commencing in 1973. Hence, O&M expenditure in any year bears no particular relationship to the investment made in that year.

[4] User charges denote the O&M component of the municipal treatment charges. The investment component is denoted under investment recovery.

Note: The Soap and Detergent industry includes the manufacturing of soap, organic and inorganic detergents, and any combination of the three.

Section Four

A COMPREHENSIVE ASSESSMENT OF POLLUTION CONTROL: IMPACT MEASUREMENT UNDER ALTERNATIVE FUTURES

This Section presents national- and sectoral-level estimates of the key economic, environmental, and energy impacts of Federal pollution control laws and regulations. These impacts are examined under different sets of basic assumptions about economic activity levels and energy conservation policies and programs. The period of 1971 through 1985 is evaluated since it includes the time frame during which the Federally mandated environmental policies will be put into effect. The analysis is conducted by running alternative scenarios through a computerized system for impact estimation and analysis; the computer system used is the Strategic Environmental Assessment System (SEAS).

The magnitude and interrelationships of estimated relative impacts are forecast based upon the assumptions made explicit in each scenario. The basic structure of the economy, and the fiscal policies which help guide it, are maintained for each specific run of the model system. Changes in these and other basic assumptions are what constitute a specific scenario.

All industrial pollution control cost functions utilized in this section are those used in the original SEAS calculations. They have not been modified by the more recent data which accompany SEAS cost estimates in Sections 2 and 3, and which have been included in nationally aggregated cost totals presented elsewhere in the report.

This situation has little effect on the analyses in this section, since the principle objective is to indicate the relative impacts of potential alternative future conditions on the national pollution control costs and residual discharges, and not to precisely define the pollution control costs for particular sectors of the economy.

Chapter 1
Impact Estimation Using The Strategic Environmental Assessment System (SEAS)

In several previous studies and reports, there have been estimates made of the projected impacts on the national economy of pollution abatement programs. The Environmental Protection Agency (e.g., see The Economics of Clean Water-1973 and The Economic Impact of the Federal Environmental Program-1974), the Council on Environmental Quality (Annual Reports), the U. S. Congress Joint Economic Committee, and other agencies have utilized a variety of economic models to project impacts upon overall price inflation and levels of economic activity. These models have included procedures developed either by the agencies themselves or by private groups, such as Chase Econometrics Associates, the Brookings Institute, and Data Resources Incorporated. For the most part, this previous work has led to forecasts indicating that the inflationary influences of pollution abatement programs would be comparatively minor relative to the presence of numerous other inflationary influences, and that the effects on national income would also be relatively minor.

Several of the previous studies of pollution abatement impacts have also devoted considerable attention to evaluating the benefits and costs attributable to pollution abatement programs. The purpose of such benefit/cost analyses has been to assess whether the nation would receive economic and environmental benefits greater than the expenditures required to achieve them.

The work described in this section departs from these previous efforts in three important ways:

- First, no attempt is made to develop a single set of impact projections; rather, impacts are measured relative to different sets of general socioeconomic assumptions of future conditions;
- Second, the analysis focuses on how these impacts are differentially affected by the various basic assumptions about future economic and pollution control activities and energy policy, rather than their absolute levels (although these are also presented);
- Third, control costs and resultant pollution estimates are developed at a greater level of industrial detail and the effect of cost feedbacks by sector are

included. (Feedbacks are purchases made for pollution control implementation and operation that increase purchases from sectors that produce such items.)

The present imprecise state of knowledge regarding the evaluation of future benefits makes any attempt to compile a national aggregate figure for benefits subject to large uncertainties. As a substitute approach, consequences of pollution abatement programs are analyzed through tradeoffs among the various costs and impacts of achieving legislated Federal control objectives.

The general procedure used for tradeoff analysis is as follows:

1. Select a consistent set of general economic, environmental, demographic and resource-energy assumptions;
2. Calculate a set of forecasts of the economy, industry outputs, environmental residuals and energy usage given that specific industry environmental controls are not increased beyond those present in 1971.
3. Calculate the same forecasts, given that environmental controls, costs, and equipment purchases are superimposed on the original economic structure as necessary to comply with Federal pollution control legislation.
4. Compare the differences in forecasts between the abatement case and the non-abatement case for national level statistics and for industry-detailed statistics.

This procedure was performed for three alternative sets of assumptions, plus one variation on environmental controls and costs. Steps 1 and 3 draw on the data provided in Sections Two and Three of this report. The forecasts required in Steps 2 and 3 are derived from operation of SEAS using these data. Step 4, the impact analysis, is a quantitative analysis of the SEAS simulation results for each scenario to determine impacts upon environmental pollution, pollution control costs, and economic and resource usage statistics. (See Appendix A for a brief description of the SEAS system used for this application.)

Chapter 2
Scenario Assumptions

Six major scenarios were constructed to develop impact estimates through 1985 for alternative sets of assumptions about the future. The six scenarios are divided into three pairs, with each pair representing a predefined "case" of future economic and energy-consumption conditions. The three cases selected for this study are a Reference Case, a Low Productivity Case, and an Energy Conservation Case.

A "non-abatement" scenario and an "abatement" or "compliance" scenario were run to provide the two alternative forecasts for each case, thereby showing the incremental impacts of pollution control. Each forecast provides annual projections through 1985 of major macroeconomic and demographic variables, industrial outputs, energy usage, domestic demand for virgin stocks, recycling levels, transportation demand, and environmental pollution levels. The first, or non-abatement scenario, estimates the value of these variables in the absence of Federal pollution control legislation after 1970. It assumes that no incremental expenditures are made by industries, utilities, and municipalities to improve pollution control beyond processes in place in 1971, and that all new industrial facilities will control pollution to the same extent as that practiced in 1971. It also assumes that Federal expenditures do not include any additional subsidies for pollution control past 1971. The non-abatement scenario, however, does allow for pollution reductions resulting from switching to new process technologies which would have occurred without Federal legislation.

The second or abatement scenario in each pair assumes that sufficient abatement expenditures are made to bring air and water pollution from industry, utility, municipal, and mobile sources into full compliance with Federal statutes. It also provides for additional Federal expenditures to cover the cost of pollution abatement at Federal plants and the cost of other Federally-sponsored pollution control programs. The abatement scenarios provide estimates of the incremental costs of pollution control through 1985, in addition to estimates of the same variables forecast in the non-abatement scenarios.

The six scenarios run for the three cases are summarized below:

Case	Non-Abatement Scenarios (Without Incremental Control Costs)	Abatement Scenarios (With Incremental Control Costs)
Reference	Scenario 1	Scenario 2
Low Productivity	Scenario 3	Scenario 4
Energy Conservation	Scenario 5	Scenario 6

The following names are used in the remainder of this Section to identify each scenario:

Scenario 1 - The Reference Scenario

Scenario 2 - The Reference Abatement Scenario

Scenario 3 - The Low Productivity Scenario

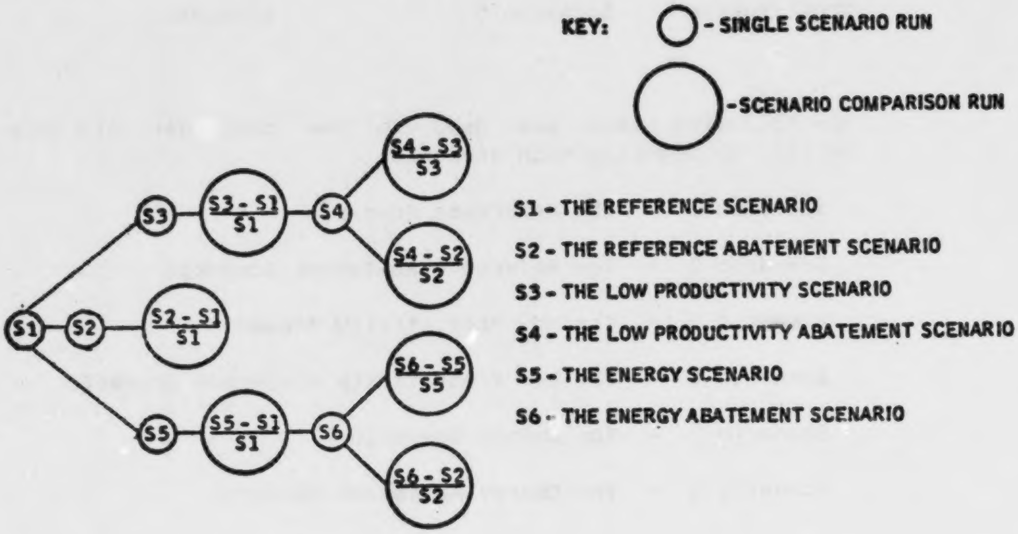
Scenario 4 - The Low Productivity Abatement Scenario

Scenario 5 - The Energy Scenario

Scenario 6 - The Energy Abatement Scenario

The six scenarios were produced in the sequence shown in Figure 1. This sequence is designed to permit a comparative analysis of the relative impacts and tradeoffs between logical scenario pairs. Certain pairs are compared to analyze the consequences of pollution control under the conditions assumed for each case: (1,2), (3,4) and (5,6). Other pairs provide an analysis of the impacts of the assumptions themselves, both in the absence of incremental abatement costs: (1,3) and (1,5); and with these costs applied: (2,4) and (2,6).

Figure 1.
Scenario Run Sequence


KEY:
- SINGLE SCENARIO RUN
-SCENARIO COMPARISON RUN
S1
S2
S3
S4
S5
S6
S2 - S1 / S1
S3 - S1 / S1
S5 - S1 / S1
S4 - S3 / S3
S4 - S2 / S2
S6 - S5 / S5
S6 - S2 / S2
S1 - THE REFERENCE SCENARIO
S2 - THE REFERENCE ABATEMENT SCENARIO
S3 - THE LOW PRODUCTIVITY SCENARIO
S4 - THE LOW PRODUCTIVITY ABATEMENT SCENARIO
S5 - THE ENERGY SCENARIO
S6 - THE ENERGY ABATEMENT SCENARIO

The objective in comparing the economic, environmental, and energy consequences of two scenarios is not to claim that one is better or more realistic than the other, but to develop an analysis that will provide meaningful abatement cost forecasts for a range of economic and energy projections. Examples of the kind of analysis afforded by constrasting scenario cases is presented below:

- **The Reference Case vs. The Low Productivity Case** - The two Reference Case scenarios call for the U.S. economy to approach full employment in the early 1980's along a relatively high productivity, high growth supply-oriented path. The alternative Low Productivity Case scenarios reflect a lower productivity and growth profile. By comparing first the Low Productivity Scenario with the Reference Scenario, and then the Low Productivity Abatement Scenario with both the Low Productivity Scenario and the Reference Abatement Scenario, one can analyze the economic, environmental, and energy consequences of implementing pollution controls with alternative labor-productivity conditions. Such an analysis affords insights into the differences in abatement cost impacts arising from two relatively realistic, but potentially very different, economic futures. By 1985, the difference in GNP due to these alternative productivity conditions is about 12 percent.

- **The Reference Case vs. The Energy Conservation Case** - The Reference Case scenarios contain a number of basic energy conservation policy measures. The alternative Energy Conservation Case scenarios provide for an even more stringent set of energy conservation policies and programs. A comparison of the Energy Scenario with the Reference Scenario, followed by comparisons of the Energy Abatement Scenario with the Energy Scenario and the Reference Abatement Scenario, affords insight into the differences in the potential economic, environmental, and energy consequences of legislated pollution controls under a range of energy consumption assumptions.

The detailed assumptions used to construct the Reference and Reference Abatement Scenarios are presented in Appendix B along with the changes in those assumptions made for the Low Productivity and the Energy Conservation Cases.

Chapter 3
Macro-Analysis Results

Results from the six SEAS scenario runs were subjected to both macro- and sector-level analyses of the estimated economic, environmental, and energy consequences of pollution control. The following discussion presents the macro-level findings, beginning with the Reference Scenario and proceeding through the selected scenarios and scenario comparisons. In addition, Appendix C presents an analysis of the Municipal Scenario, a variant of the Reference Abatement Scenario that assumes a continuing appropriation of $7 billion a year for municipal sewage treatment facilities through the 1976-1985 decade.

A summary of the major results from the SEAS scenarios is presented in Table 1. These results show that, over the decade 1976-85, the total cost of complying with Federal air and water pollution control legislation constitutes a relatively small portion of the decade's cumulative gross national product (GNP). Total decade abatement costs, as a percentage of GNP, range from 2.09 percent for the Reference Case to 2.25 percent for the Reference Case variant identified above as the Municipal Scenario.

Table 1 indicates a fairly constant increase in energy use by 1985 of 4.2 to 4.9 quadrillion Btu's resulting from the addition of pollution abatement practices in each of the four abatement scenarios. It also shows the reduction in net residuals (residuals discharged to the environment either before or after treatment) achieved by 1985 as a percentage of the Reference Scenario forecasts for each of five air and four water pollutants. In general, the greatest abatement (reduction of residuals released to the carrier medium) is attained in the Low Productivity Case, except for the lower amounts of biochemical oxygen demand (BOD), suspended solids, and nutrients are achieved in the Municipal Scenario.

The annual composition of detailed data on the economy, energy use, resource demand, pollutant residuals, and abatement costs are presented in the individual scenario analyses which follow.

Table 1.
Summary of Scenario Results

Scenario	1976-85 Decade GNP (Trillion 1975$)	1976-85 Incremental Decade Pollution[1] Control Cost (% GNP)	1985 Energy Consumption (Quad Btu's)	Net Residuals in 1985[2] (% of Reference)								
				SO	Part	NO	HC	CO	BOD	SS	DS	Nut.
Reference	20.007		109.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Reference Abatement	20.153	2.09	113.5	38.5	14.0	91.4	39.5	23.6	21.9	9.8	62.3	80.5
Municipal	20.181	2.25	113.9	38.6	14.1	91.7	39.5	23.6	15.0	5.6	62.4	28.4
Low Productivity	18.596		102.0	90.4	90.6	88.5	87.2	84.7	92.4	91.3	88.3	99.1
Low Productivity Abatement	18.804	2.22	106.2	34.6	12.5	81.6	35.2	20.3	20.5	9.4	55.0	80.1
Energy	20.062		95.7	89.8	96.4	91.8	86.3	86.3	99.5	99.0	96.1	00.0
Energy Abatement	20.187	2.13	100.4	35.2	13.5	84.8	35.0	21.5	21.8	9.9	59.6	80.5

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[1] See Tables 4, 12, and 21 in this chapter and Table C-1 in Appendix C, for composition of pollution control costs by year from 1976 through 1985.

[2] SO = Sulfur Oxides, Part = Particulates, NO = Nitrogen Oxides, HC = Hydrocarbons, CO = Carbon Monoxide, BOD = Biochemical Oxygen Demand, SS = Suspended Solids, DS = Dissolved Solids, Nut. = Nutrients

THE REFERENCE SCENARIO

The Reference Scenario, which acts as the baseline for all subsequent projections, includes the general forecast assumptions described below. (See Appendix B for a detailed discussion of these assumptions.)

1. High productivity and government policy to achieve a full-supply labor force economy by the mid-1980s will produce a 1985 GNP of $2.36 trillion (1975 constant dollars) with an unemployment rate of 4.4 percent for a projected labor force of 107.7 million civilian workers.

2. No municipal or industrial process will increase its pollution control treatment efficiency levels above those in use during 1971.

3. Energy usage and conservation will be consistent with energy forecasts of the $7.00/barrel "Business-as-Usual Without Conservation" scenario of Project Independence, with an aggregate energy requirement of 109 quadrillion Btu's in 1985.

Based on these assumptions, the Reference Scenario forecast was projected over the decade 1976-85. Some general statistics that characterize the baseline projections appear in Table 2.

The picture of the national economy for this baseline is one in which the economy will gradually grow out of the 1975 recession to achieve an unemployment rate of 4.4 percent by 1985. GNP grows at a 6.5 percent rate between the years 1975-80 and at a 4.0 percent rate between 1981-85.

Over the decade, the personal consumption expenditures and equipment investment components of the GNP show greater growth rates than the overall GNP growth rate. Non-Federal government expenditures increase at rates well ahead of the increases in the exogenously set Federal expenditures level (4.4 percent annual increase compared to 1.6 percent).

Total industrial output grows at a rate somewhat greater than GNP with the sectors related to agriculture and mining showing the slowest rates of growth, manufacturing sectors growing at a rate slightly less than that for total output, and the sectors related to services, transportation, communications, and electric utilities exhibiting the highest growth rates. The slowdown in the growth rate for the GNP in the years 1980-85 as the country catches up from the downturn of the early Seventies is also reflected in decreasing rates for most of these industrial output growth rates.

The energy requirement to support this economic pattern reflects a growing demand for electricity. By 1985, coal and nuclear sources will account for 63 percent of all energy used in electrical generation, with coal accounting for 33 percent. Growth in natural gas, petroleum and coal usage to meet non-electrical energy demands on an annual rate basis over the decade is 1.1 percent, 2.8 percent and 3.8 percent, respectively.

Table 2.
General Projections of the Reference Scenario (S1),
1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Population (Millions)	215.80	217.70	219.80	221.90	224.10	226.40	228.70	231.00	233.40	235.70
Labor Force (Millions)	95.40	97.00	98.60	100.20	101.80	103.20	104.50	105.70	106.70	107.70
Unemployment Rate (%)	7.90	7.10	6.00	5.50	5.10	5.30	4.80	4.60	4.50	4.40
Disposable Income Per Capita (1,000 1975 $)	5.62	5.99	6.61	7.04	7.54	7.73	8.07	8.31	8.55	8.78
Gross National Product (Trillion 1975 $)	1.56	1.67	1.77	1.89	2.01	2.08	2.15	2.22	2.29	2.36
Personal Consumption Expenditures	0.97	1.02	1.12	1.19	1.28	1.32	1.39	1.46	1.51	1.56
Investment	0.26	0.29	0.29	0.32	0.34	0.35	0.36	0.36	0.37	0.38
Government Expenditures	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.41
Federal	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.14
Other	0.20	0.21	0.22	0.23	0.24	0.25	0.25	0.26	0.27	0.27
Total Output (Trillion 1975 $)	2.61	2.80	2.98	3.19	3.41	3.53	3.67	3.80	3.93	4.07
Total Energy Use (Quadrillion Btu's)	79.97	83.48	86.63	90.12	93.62	96.40	99.40	102.50	105.68	109.01
Natural Gas	19.06	18.96	19.43	19.92	20.43	20.59	20.83	21.05	21.26	21.47
Petroleum	31.36	32.38	33.40	34.52	35.58	36.52	37.43	38.37	39.28	40.19
Coal	4.59	4.89	5.01	5.28	5.55	5.67	5.80	5.94	6.08	6.24
Electricity	24.95	27.26	28.78	30.40	32.06	33.61	35.33	37.14	39.06	41.11
U.S. Demand (Million Metric Tons)										
Copper	3.20	3.55	3.73	3.93	4.13	4.19	4.27	4.37	4.46	4.52
Iron	141.97	150.81	149.40	158.88	167.44	168.13	168.12	169.26	170.81	172.75
Aluminum	5.65	6.15	6.42	6.89	7.38	7.61	7.81	8.05	8.30	8.57
Recycled Materials (Million Metric Tons	65.76	69.73	72.75	76.72	80.95	83.25	85.70	88.41	90.77	92.95
Paper/Paperboard	6.19	6.62	7.16	7.67	8.20	8.50	8.86	9.19	9.51	9.84
Aluminum	1.48	1.64	1.70	1.88	2.09	2.28	2.23	2.47	2.60	2.68
Ferrous Metals	38.26	40.27	41.33	43.13	44.99	46.06	47.17	48.29	49.18	49.94

Table 2. (Continued)
General Projections of the Reference Scenario (S1),
1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Total Vehicle Kilometers (Trillions)	1.62	1.70	1.85	1.94	2.05	2.11	2.21	2.28	2.35	2.42
Auto	1.61	1.68	1.83	1.92	2.03	2.09	2.19	2.26	2.33	2.40
Total Freight Metric Ton-Kilometers (Billions)	3.55	3.76	3.92	4.14	4.35	4.49	4.64	4.80	4.96	5.13
Truck	0.73	0.79	0.83	0.89	0.95	1.00	1.04	1.09	1.14	1.20
Rail	1.14	1.21	1.25	1.31	1.37	1.41	1.45	1.49	1.53	1.57
Net Air Residuals (Million Metric Tons)										
Particulates	30.37	32.43	33.85	35.61	37.41	38.15	38.99	39.95	40.94	42.00
Sulfur Oxides	36.74	39.87	41.14	42.59	44.12	44.61	45.37	46.25	47.26	48.44
Nitrogen Oxides	18.65	20.00	21.07	22.07	23.18	23.77	24.60	25.39	26.24	27.16
Hydrocarbons	12.17	12.42	13.02	13.46	14.01	14.28	14.75	15.14	15.55	15.94
Carbon Monoxide	70.30	74.10	79.80	84.20	89.20	91.90	96.10	99.30	102.50	105.70
Net Water Residuals (Million Metric Tons)										
Biochemical Oxygen Demand	4.23	4.44	4.68	4.89	5.12	5.24	5.40	5.55	5.69	5.84
Suspended Solids	9.78	10.31	10.67	11.20	11.77	11.97	12.18	12.41	12.64	12.89
Dissolved Solids	12.06	12.57	13.14	13.68	14.23	14.33	14.51	14.66	14.80	14.95
Nutrients	1.19	1.21	1.23	1.26	1.28	1.30	1.33	1.35	1.37	1.40
Incremental Air Control Costs										
Investment[1]	0	0	0	0	0	0	0	0	0	0
Annualized Costs	0	0	0	0	0	0	0	0	0	0
Capital[2]	0	0	0	0	0	0	0	0	0	0
O&M	0	0	0	0	0	0	0	0	0	0
Capital in Place	0	0	0	0	0	0	0	0	0	0
Direct Employment	0	0	0	0	0	0	0	0	0	0

Table 2. (Continued)
General Projections of the Reference Scenario (S1), 1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Incremental Water Industrial Costs										
Investment	0	0	0	0	0	0	0	0	0	0
Annualized Costs	0	0	0	0	0	0	0	0	0	0
Capital	0	0	0	0	0	0	0	0	0	0
O&M	0	0	0	0	0	0	0	0	0	0
Capital in Place	0	0	0	0	0	0	0	0	0	0
Direct Employment	0	0	0	0	0	0	0	0	0	0
Incremental Water Municipal Costs										
Investment	0	0	0	0	0	0	0	0	0	0
Annualized Costs	0	0	0	0	0	0	0	0	0	0
Capital	0	0	0	0	0	0	0	0	0	0
O&M	0	0	0	0	0	0	0	0	0	0
Capital in Place	0	0	0	0	0	0	0	0	0	0
Direct Employment	0	0	0	0	0	0	0	0	0	0

[1] Includes state transportation control costs and mobile source pollution abatement expenditures.

[2] Annualized to include interest on all investments, including those for mobile source controls.

Resource demand projections for the Reference Scenario indicate increasing requirements for virgin ore resources. For example, U.S. demand for iron ore increases at an average annual rate of slightly over 2 percent per year over the period, with higher rates during the 1970 decade. Similar demand patterns, but with slightly higher rates of increase, are noted for both aluminum and copper ores. This usage reflects the growth pattern shown in Table 2 for total output, with the annual growth rates of the late 1970's two times or more the rates for the early 1980's. The patterns noted for these metal ores are also found in the demand statistics for recycling of paper/paperboard, aluminum and ferrous metals. Demand for recycled aluminum is particularly heavy over the decade, averaging about 8 percent growth per year.

As a final set of characterizations of the Reference Scenario, the following patterns can be noted for annual levels of air and water residuals released to the environment.

First, the annual growth rates for all air- and water-borne residuals are less than the economic growth rate and are less than the manufacturing output growth rate. Thus, even with no improved treatment efficiencies past 1971, relative improvement in residuals per dollar of output produced are noted for all major residuals categories due to increasing use of cleaner production technologies. However, the change is relatively small, and the absolute levels of annual residual loads continue to increase for all air and water residual categories throughout the decade.

Second, the decade projections also show that air residuals are increasing at rates greater than the water residuals. To provide greater detail on growth rates by generation source (i.e., industrial, municipal, transportation, or electric utilities), Figures 1 and 2 are provided for evaluation and comparison. The data in Figures 1 and 2 demonstrate that although the growth rates of air residuals connected with mobile sources are greater than those for stationary sources, the growth rate of air residuals from any source is consistently higher than the growth rate of water residuals.

Finally, Table 3 presents the change in stationary source treatment efficiencies from 1975 through 1985. These efficiencies are calculated as gross residuals less net residuals divided by gross residuals, where:

- Gross residuals equal the residuals that would occur if there were no end-of-process treatment of discharges.

- Net residuals equal the residuals that occur due to end-of-process treatment of discharges by each industrial process.

Figure 1.
Trends in Air Residuals in Reference Scenario

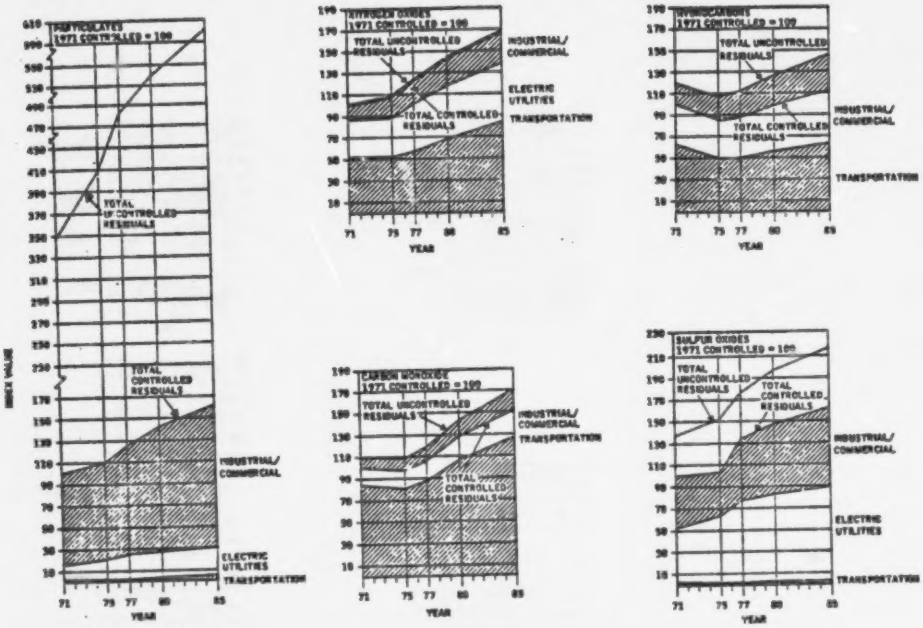

Figure 2.
Trends in Water Residuals in Reference Scenario(1971-1985)

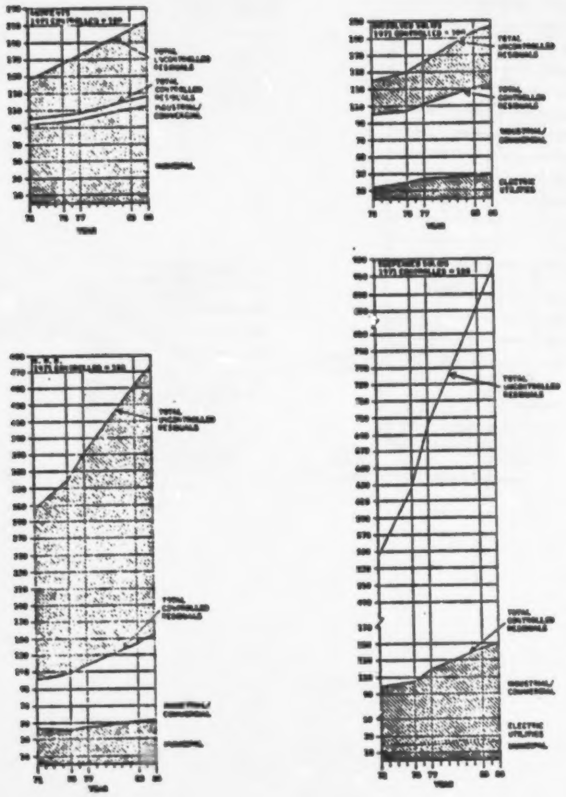

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Table 3.
Relative Stationary Source Treatment Efficiencies of Selected Pollutants for the Reference Scenario
(Efficiencies in Percent of Residuals Removed)

	1975	1980	1985
Air Residuals			
Particulates	73.66	74.05	73.83
Sulfur Oxides	23.89	23.26	23.54
Nitrogen Oxides	0.23	0.24	0.26
Hydrocarbons	39.69	39.66	41.41
Carbon Monoxide	46.46	46.68	48.07
Water Residuals			
Biochemical Oxygen Demand	69.02	67.74	67.57
Suspended Solids	82.82	83.11	83.68
Dissolved Solids	31.10	32.43	34.57
Nutrients	35.42	38.97	40.88

In the case of air residuals, the treatment efficiencies are relatively constant, suggesting only minor improvements from switches in industrial processes used for the abatement of air emissions. On the other hand, the treatment efficiencies for water residuals exhibit small increases over the decade (with the exception of BOD). This suggests that industrial sectors which had higher efficiency treatment processes for water residuals as of 1971 are growing faster than those industrial sectors with less efficient processes.

In summary, environmental forecasts from the Reference Scenario behave as would be expected with the calibration of macroeconomic indicators to a high-growth, high-productivity set of assumptions. Economic growth and resource usage are greatest in the period 1975-80, with all annual growth rates considerably slowed in 1980-85. Environmental residuals are also increasing, but the annual growth rates are less than the annual economic growth rates. Between air and water residuals, the air residuals consistently show the greatest annual growth rates.

COMPARISON OF THE REFERENCE AND REFERENCE ABATEMENT SCENARIOS

The Reference Scenario assumptions were changed in the following ways to provide a scenario that approximated the Reference Scenario, but which also included the effects and costs of Federal air and water pollution control regulations:

1. All Federally mandated treatment efficiencies and associated cost functions for control processes to achieve these efficiencies were introduced into the calculations.

2. All forecast capital and operation and maintenance (O&M) pollution control costs were fed back into the economy as increased interindustry purchases and labor requirements on an annual basis.

3. The additional labor force required for pollution control was assumed to be provided by reducing unemployment until the commonly accepted minimum level of 4 percent was reached. If in any year, unemployment under abatement conditions fell below 4 percent, then final demand was reduced through adjustment of Personal Disposal Income until an unemployment rate equal to or slightly greater than 4 percent was produced.

The results of this new scenario, the Reference Abatement Scenario, are compared to those of the Reference Scenario in the analysis that follows.

Under the schedule of compliance with Federal regulations for the Reference Abatement Scenario, some of the capital expenditures for pollution control devices occur as early as 1971; hence the 1975 data between the two scenarios exhibit some differences. Table 4, which is comparable to Table 2 for the Reference Scenario, presents summary statistics for the Reference Abatement Scenario. The values of the various statistics for the years 1976 through 1985 provide a useful means of comparing relative growth rates for the two scenarios. Note that the costs and additional industrial output associated with compliance in the Reference Abatement Scenario act as a stimulus to GNP, total output and employment.

In the period 1976-79, since there was sufficiently high unemployment, the additional labor force required to carry out the mandated pollution abatement activities is transferred from idle resources, thus resulting in a net benefit to the economy. From 1980-85 however, the required level of labor needed for pollution abatement is in excess of the amount available, and so labor resources must be taken away from other competing needs. Even in these years, the fact that there are some unemployed resources before abatement controls were mandated means that the GNP increases in all years. Among the industries required to implement abatement technologies, those that supply abatement equipment and materials are impacted at various levels. Although all supplying industries are required to shift revenues away from production to pollution control in their processes, some receive enough orders from other industries to offset or more than offset the intra-industry shifts. These industries are net gainers (i.e., platinum), while remaining industries are net losers (i.e., agriculture).

Table 4
General Projections of the Reference Abatement Scenario (S2), 1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Population (Millions)	215.80	217.70	219.80	221.90	224.10	226.40	228.70	231.00	233.40	235.70
Labor Force (Millions)	95.40	97.00	98.60	100.20	101.80	103.20	104.50	105.70	106.70	107.70
Unemployment Rate (%)	6.40	5.40	4.40	4.40	4.60	4.50	4.40	4.20	4.10	4.10
Disposable Income Per Capita (1,000 1975 $)	5.62	5.98	6.61	7.02	7.48	7.73	8.01	8.29	8.52	8.72
Gross National Product (Trillion 1975 $)	1.59	1.69	1.80	1.91	2.02	2.09	2.16	2.23	2.30	2.37
Personal Consumption Expenditures	0.97	1.03	1.12	1.19	1.27	1.33	1.39	1.45	1.50	1.56
Investment	0.28	0.30	0.30	0.33	0.35	0.36	0.36	0.37	0.37	0.38
Gov Expenditures	0.32	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.41	0.42
Federal	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.14	0.14
Other	0.20	0.22	0.23	0.24	0.25	0.25	0.26	0.27	0.27	0.28
Total Output (Trillion 1975 $)	2.66	2.86	3.04	3.24	3.44	3.57	3.69	3.82	3.95	4.08
Total Energy Use (Quadrillion Btu's)	82.81	86.45	89.81	93.37	96.78	99.94	102.97	106.30	109.95	113.51
Natural Gas	19.61	19.56	20.06	20.56	21.03	21.27	21.47	21.72	22.03	22.25
Petroleum	32.65	33.49	34.47	35.59	36.61	37.66	38.61	39.62	40.64	41.62
Coal	4.80	5.11	5.25	5.46	5.66	5.78	5.89	6.02	6.16	6.31
Electricity	25.77	28.29	30.03	31.76	33.49	35.22	37.00	38.95	41.12	43.33
U.S. Demand (Million Metric Tons)										
Copper	3.32	3.69	3.86	4.05	4.21	4.27	4.34	4.41	4.47	4.53
Iron	146.13	155.72	155.36	161.92	167.29	168.23	166.80	167.25	168.04	169.77
Aluminum	5.81	6.33	6.60	7.03	7.45	7.69	7.86	8.08	8.30	8.57
Recycled Materials (Million Metric Tons)	66.56	70.59	73.64	77.31	81.10	83.61	85.80	88.47	90.84	92.97
Paper/Paperboard	6.23	6.66	7.20	7.68	8.18	8.51	8.83	9.18	9.51	9.82
Aluminum	1.51	1.67	1.72	1.90	2.10	2.29	2.23	2.47	2.60	2.68
Ferrous Metals	38.81	40.85	41.96	43.57	45.19	46.29	47.31	48.40	49.28	50.06

Table 4. (Continued)
General Projections of the Reference Abatement Scenario (S2), 1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Total Vehicle Kilometers (Trillions)	1.62	1.70	1.85	1.93	2.03	2.11	2.19	2.27	2.35	2.41
Auto	1.61	1.68	1.83	1.92	2.02	2.09	2.17	2.25	2.33	2.39
Total Freight Metric Ton-Kilometers (Billions)	3.66	3.87	4.04	4.24	4.43	4.58	4.72	4.89	5.05	5.22
Truck	0.75	0.81	0.86	0.91	0.97	1.02	1.06	1.11	1.17	1.22
Rail	1.18	1.24	1.29	1.34	1.40	1.44	1.47	1.51	1.56	1.60
Net Air Residuals (Million Metric Tons)										
Particulates	12.68	8.29	8.51	8.85	9.17	9.34	8.50	7.66	6.86	5.87
Sulfur Oxides	19.31	14.61	15.28	15.94	16.61	17.03	17.33	17.72	18.17	18.63
Nitrogen Oxides	18.59	19.81	20.75	21.46	22.19	22.61	23.25	23.82	24.29	24.83
Hydrocarbons	10.09	9.49	9.41	9.15	8.92	8.59	8.00	7.38	6.86	6.29
Carbon Monoxide	55.76	52.61	50.73	47.35	43.85	39.95	35.12	31.52	27.68	24.90
Net Water Residuals (Million Metric Tons)										
Biochemical Oxygen Demand	3.18	2.75	2.26	2.23	2.20	2.01	1.81	1.59	1.37	1.28
Suspended Solids	6.51	4.84	2.86	2.87	2.90	2.53	2.15	1.76	1.34	1.27
Dissolved Solids	11.48	11.49	11.54	11.94	12.32	11.39	10.50	9.72	9.03	9.31
Nutrients	1.14	1.13	1.12	1.13	1.13	1.13	1.13	1.12	1.12	1.12
Incremental Air Control Costs (Billion 1975 $)										
Investment[1]	6.38	8.32	10.69	8.08	7.22	7.15	6.87	6.70	6.65	6.84
Annualized Costs										
Capital[2]	7.38	8.59	10.88	12.80	14.47	15.85	16.95	17.78	18.36	18.72
O&M	8.73	8.09	8.10	9.00	9.68	10.22	10.66	11.07	11.49	11.93
Capital in Place	37.64	44.22	53.69	60.67	65.99	70.40	73.81	76.35	78.20	79.54
Direct Employment (Thousands)	14	17	18	20	21	21	21	20	20	20

Table 4. (Continued)
General Projections of the Reference Abatement Scenario (S2),
1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Incremental										
Water Industrial Costs (Billion 1975 $)										
Investment	3.55	5.67	3.25	5.05	6.38	5.76	6.97	5.31	1.36	1.64
Annualized Costs										
Capital	1.99	2.73	3.15	3.81	4.64	5.39	6.30	6.99	7.15	7.35
O&M	3.64	4.80	5.85	6.31	6.74	7.08	7.29	7.59	10.74	11.17
Capital in Place	15.12	20.79	23.98	28.97	35.29	40.99	47.90	53.15	53.38	55.88
Direct Employment (Thousands)	114	150	183	198	211	222	229	238	352	367
Incremental										
Water Municipal Costs (Billion 1975 $)										
Investment	6.55	8.11	8.13	5.59	2.94	1.77	0.80	0.70	0.70	0.53
Annualized Costs										
Capital	2.27	3.17	4.06	4.68	5.00	5.20	5.28	5.36	5.44	5.50
O&M	0.68	0.93	1.36	1.61	1.76	1.84	1.89	1.93	1.97	2.00
Capital in Place	20.63	28.74	36.88	42.47	45.41	47.17	47.97	48.67	49.37	49.90
Direct Employment (Thousands)	20	27	40	48	52	54	56	57	58	59

[1] Includes state transportation control costs and mobile source pollution abatement expenditures.

[2] Annualized to include interest on all investments, including those for mobile source controls.

Table 5 provides a comparison of a number of scenario statistics from the Reference Abatement Scenario with the same values developed in the Reference Scenario for each of five years. (This comparison uses the Reference Scenario as a normalizing base, i.e. (S2-S1)/S1.) Table 6 presents pollution control costs by type throughout the decade as a percent of GNP.

When looked at in comparative terms, the costs of pollution control are relatively small for the Reference Abatement Scenario. Both GNP, as noted earlier, and the output of total goods and services increase throughout the decade. Moreover, the introduction of these controls (given the assumptions stated) is favorable for most factors of final demand, such as Federal expenditures and investment. Further, the change in production processes and the shift in the mix of goods and services produced eventually results in a lesser requirement for some of our natural resources, with paper and iron ore being noticeable examples by 1985. However, during the phase of major new capital development (period to 1980), these same resources (and others) actually are used at higher rates, particularly during the early part of this time period. Finally, results in the reduction of the air and water residuals released to the environment are reduced. Except for nitrogen oxides (-8.66 percent), nutrients (-19.51 percent), and dissolved solids (-37.72 percent), these reductions are all greater than 60 percent. Thus, over half of most residuals released to the environment without pollution control are captured in the Reference Abatement Scenario.

Table 5.
Comparison of the Macro-Statistics of the Reference Abatement Scenario (S2) and the Reference Scenario (S1)
[(S2-S1)/S1 in %]

Statistic	1975	1977	1980	1983	1985
Gross National Product	1.92	1.68	0.43	0.34	0.96
Disposable Income Per Capita	0	0	-0.82	-0.34	-0.59
Total Employment	1.99	1.80	0.46	0.43	0.24
Federal Expenditures	0.24	1.07	2.24	2.20	2.17
Personal Consumption Expenditures	0.53	0.25	0.41	-0.09	-0.21
Total Output	2.27	2.01	0.71	0.59	0.37
Investment	7.26	5.24	2.44	1.08	0
Energy Use	3.78	3.55	3.37	3.71	4.13
Demand: Iron	3.99	3.25	0.10	-1.19	-1.73
Aluminum	3.38	3.01	0.97	0.37	-0.06
Recycling: Paper/Paperboard	0.67	0.63	-0.25	-0.11	-0.21
Aluminum	3.39	3.01	0.98	0.37	-0.06
Ferrous Metals	3.23	2.76	0.77	0.12	-0.28
Vehicle Kilometers	0	0	-0.82	-0.34	-0.59
Freight Metric Ton-Kilometers	3.41	2.96	1.82	1.78	1.85
Net Air Residuals:					
Particulates	-41.15	-74.69	-75.50	-80.83	-86.03
Sulfur Oxides	-32.67	-63.36	-62.36	-61.69	-61.54
Nitrogen Oxides	0.10	-0.95	-4.30	-6.21	-8.56
Hydrocarbons	-13.50	-23.63	-36.34	-51.24	-60.52
Carbon Monoxide	-19.00	-28.99	-50.57	-68.27	-76.45
Net Water Residuals:					
Biochemical Oxygen Demand	-11.72	-38.04	-57.14	-71.26	-78.14
Suspended Solids	-14.18	-52.09	-75.40	-85.85	-90.17
Dissolved Solids	-0.91	-8.58	-13.41	-33.71	-37.72
Nutrients	-1.97	-6.20	-11.98	-16.62	-19.47

Table 6.
Incremental Pollution Control Costs as a Percentage of Reference Scenario GNP

	1977	1980	1983	1985	1976-85
Air Stationary Source Costs					
Annual Capital Cost	0.28	0.30	0.29	0.28	0.29
O&M Cost	0.26	0.28	0.25	0.24	0.26
Water Industrial Costs					
Annual Capital Cost	0.16	0.23	0.31	0.31	0.25
O&M Cost	0.28	0.33	0.34	0.47	0.35
Water Municipal Costs					
Annual Capital Cost	0.19	0.25	0.24	0.24	0.23
O&M Cost	0.06	0.09	0.09	0.08	0.08

The effects on environmental residuals in the Reference Abatement Scenario are, as noted above, generally substantial, but quite different patterns and relative efficiencies emerge when these effects are compared with those resulting from the 1971 control technologies of the Reference Scenario. For example, the air residuals shown in Table 7 reflect this differential effect:

- For particulates and sulfur oxides, the level of maximum efficiency is nearly realized by 1980 with minor changes after that time. Since the primary emitters are stationary sources and existing plants are assumed to be in full compliance with Federally mandated pollution control standards by 1980, this time pattern is expected. Further small improvement can be noted after 1980 for particulates; this is due to the more stringent regulations on new facilities.

- For nitrogen oxides, the relative levels of treatment are so minimal that the level of annual residuals from industries increases at nine-tenths the rate of economic output. About 60 percent of all nitrogen oxide residuals in 1985 are released by stationary sources. For vehicle emissions, the rate of improvement in treatment efficiencies is somewhat better, but still so marginal that an increase in annual levels of total nitrogen oxides released to the air is noted. Table 8 provides data for nitrogen oxide from passenger transportation, showing a 39 percent reduction in emissions per kilometer in 1985 as compared to the 1975 control levels.

For the final two air residual categories, hydrocarbons and carbon monoxide, significant improvements in treatment efficiencies by 1985 are noted as shown in Table 8, with the improvements in post-1980 efficiencies continuing to be significant. This effect, unlike that seen for particulates, is because the chief emitters of hydrocarbons and carbon monoxide are mobile sources of considerable vintage. Since retrofit equipment is not a part of the assumed pollution controls, the steady state condition of almost all automobiles having emission characteristics similar to the most stringent standards will not occur until about 1995 when most of the 1975-and-earlier vintage automobiles will have been retired. Thus, delays in meeting specific mobile source standards will be reflected in higher annual emissions for these two air residual categories for periods up to two decades later.

Table 7.
Relative Stationary Source Treatment Efficiencies of Selected Pollutants for the Reference and Reference Abatement Scenarios
(Efficiencies in Percent of Residuals Removed)

	1975		1980		1985	
	Reference	Reference Abatement	Reference	Reference Abatement	Reference	Reference Abatement
Air Residuals						
Particulates	73.66	85.33	74.05	94.06	73.83	96.96
Sulfur Oxides	23.89	51.24	23.26	72.93	23.54	72.27
Nitrogen Oxides	0.23	2.53	0.24	5.64	0.26	5.65
Hydrocarbons	39.69	50.79	39.66	59.30	41.41	70.91
Carbon Monoxide	46.46	62.14	46.68	72.75	48.07	76.17
Water Residuals						
Biochemical Oxygen Demand	69.02	72.43	67.74	86.17	67.57	92.91
Suspended Solids	82.82	85.78	83.11	96.07	83.68	98.50
Dissolved Solids	31.10	33.80	32.43	43.84	34.57	61.15
Nutrients	35.42	37.26	38.97	47.45	40.88	53.83

Table 8.
Passenger Transportation Emission Levels for the Reference and Reference Abatement Scenarios
(Metric Tons per Million Vehicle Kilometers Travelled)

	1975		1980		1985	
Air Residuals	Reference	Reference Abatement	Reference	Reference Abatement	Reference	Reference Abatement
Particulates	0.22	0.18	0.21	0.16	0.21	0.14
Sulfur Oxides	0.08	0.08	0.08	0.08	0.08	0.08
Nitrogen Oxides	1.94	1.82	1.92	1.60	1.91	1.11
Hydrocarbons	2.65	2.28	2.21	1.25	2.13	0.52
Carbon Monoxide	22.05	17.91	22.30	10.48	22.48	3.65

The water residuals of the Reference Abatement Scenario shown in Table 7 exhibit the following patterns:

- For BOD and total suspended solids, significant improvement occurs throughout the decade, with high points coinciding with the regulatory years for BPT and BAT (1977 and 1983). Since most suspended solids are treated within industrial plants, the required high-efficiency level for industry is reflected in the overall treatment efficiency of 96.1 percent in 1980 and 98.5 percent in 1985. For BOD, however, the existing pre-1971 BOD removal efficiencies at municipal plants result in an improvement of only 74 percent from 1971 efficiencies by 1985.. The actual treatment efficiency achieved by 1985 is 93 percent of the BOD and 98.5 percent of the suspended solids that would have occurred if no treatment took place.

- For total dissolved solids, the Federal controls produce some relative improvements in treatment efficiency by 1977, the BPT compliance year, and then increase that treatment efficiency by over 50 percent by 1985. Even in 1985, however, the actual treatment efficiency is only about 61 percent.

- For nutrients, the relative treatment efficiencies improve from about 37 percent in 1975 to 54 percent in 1985. This improvement occurs primarily as a result of the growth in tertiary treatment by municipal plants.

Thus, it appears that the Reference Abatement Scenario has positive impacts compared to the Reference Scenario for both environmental effects and effects on the general economy. Areas that suffer adverse impacts do exist and are found primarily as demand for higher resource usage.

In energy requirements, the Reference Abatement Scenario generates an overall demand requiring a 3.4 percent increase for 1980 and 4.1 percent by 1985. The annual rates of growth compared to the Reference Scenario over the decade are similar, as are demands for specific energy sources. The reasons for the increased demand are both the additional energy requirements resulting from the generally higher economic output associated with control device purchases and the energy needed to operate these devices.

Iron, aluminum and copper usage also reflects the stimulated manufacturing output levels, as does recycling of paper/paperboard, aluminum and ferrous materials. However, material resource usage decreases after completion of the major pollution capital investments while energy continues to grow due to operating demands from the pollution equipment.

Finally, the comparison of the demand for transportation reveals that passenger vehicle-kilometers are slightly less in the Reference Abatement Scenario after 1980. The increase in freight metric-ton kilometers over the decade in the Reference Abatement Scenario is, however, relatively steady and reflects higher manufacturing shipments.

Prior to presenting a detailed analysis of sector effects for the Reference Case scenarios, the other two scenario pairs are analyzed. This will provide an appreciation of the effects of abatement policies under changes in those parts of the national economy that are outside the control of environmental policy makers.

COMPARATIVE ANALYSIS FOR THE LOW-PRODUCTIVITY SCENARIOS

The Low Productivity Case scenarios represent a low point on the range of economic conditions; this allows for a greater appreciation of the relative impacts of abatement regulations under different economic conditions. The two scenarios are labelled the Low Productivity Scenario and the Low Productivity Abatement Scenario. The principal difference between the Reference Case scenarios and the Low Productivity Case scenarios is that the basic data for labor productivity in each industry and the expenditures which comprise the GNP elements were used directly from the INFORUM-supplied data base for the Low Productivity Scenario and the Low Productivity Abatement Scenario. (INFORUM is the interindustry, input-output forecasting model which was used to produce economic forecasts for SEAS. A summary of this model is provided in Appendix A.) Use of this set of data results in a less optimistic economic forecast relative to the Reference Scenario after 1977, as shown in Figure 3. In going from the Low Productivity Scenario to the Low Productivity Abatement Scenario, the same steps were taken as in going from the Reference Scenario to the Reference Abatement Scenario.

A summary of the Low Productivity Scenario results is presented in Table 9. Table 10 provides a comparison of these results to the Reference Scenario, which also includes no incremental pollution control costs or effects. In terms of GNP, the Low Productivity Scenario results for 1975 are greater than the projections used in the Reference Scenario. By 1977, the two scenarios have nearly equal GNP's, and then the lower productivity assumptions rapidly reduce the level of GNP so that by 1985 it is nearly 12 percent lower than GNP in the Reference Scenario ($2.08 versus $2.36 trillion, in constant 1975 dollars).

Figure 3.
Scenario Projections of GNP
(1971 Abatement Control Levels)

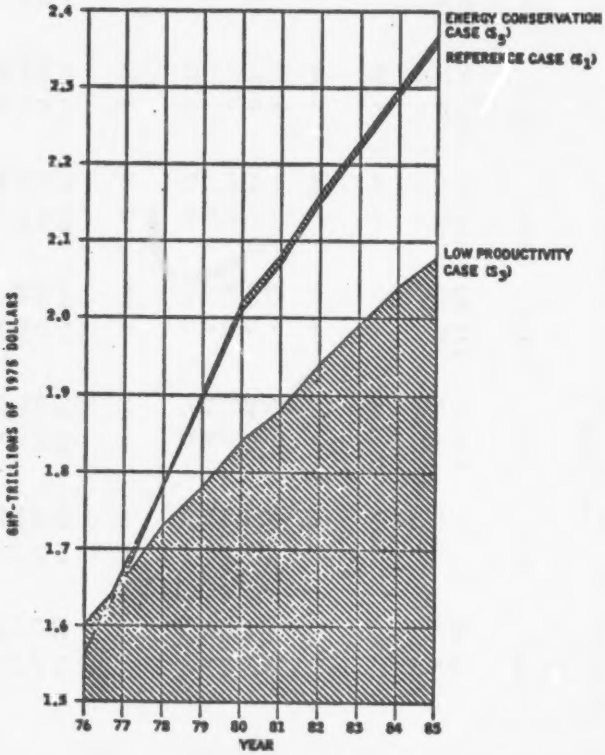


Table 9.
General Projections of the Low Productivity Scenario (S3), 1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Population (Millions)	215.80	217.70	219.80	221.90	224.10	226.40	228.70	231.00	233.40	235.70
Labor Force (Millions)	95.40	97.00	98.60	100.20	101.80	103.20	104.50	105.70	106.70	107.70
Unemployment Rate (%)	7.90	7.20	6.10	5.50	5.20	5.30	4.90	4.70	4.50	4.40
Disposable Income Per Capita (1,000 1975 $)	5.92	6.05	6.46	6.57	6.76	6.85	7.07	7.12	7.26	7.33
Gross National Product (Trillion 1975 $)	1.60	1.66	1.73	1.78	1.84	1.88	1.94	1.99	2.04	2.08
Personal Consumption Expenditures	0.99	1.03	1.10	1.13	1.17	1.21	1.25	1.28	1.32	1.36
Investment	0.27	0.28	0.28	0.28	0.29	0.30	0.31	0.31	0.32	0.33
Government Expenditures	0.31	0.32	0.33	0.34	0.35	0.35	0.36	0.37	0.38	0.38
Federal	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.13	0.13	0.13
Other	0.20	0.21	0.22	0.23	0.23	0.23	0.24	0.24	0.25	0.25
Total Output (Trillion 1975 $)	2.68	2.80	2.91	3.01	3.12	3.20	3.32	3.40	3.50	3.59
Total Energy Use (Quadrillion Btu's)	81.28	83.64	85.62	87.46	89.27	91.45	94.23	96.66	99.36	102.04
Natural Gas	19.43	18.99	19.15	19.20	19.28	19.33	19.52	19.58	19.70	19.77
Petroleum	31.91	32.48	33.07	33.59	34.03	34.74	35.59	36.31	37.05	37.77
Coal	4.71	4.86	4.86	4.93	5.02	5.10	5.25	5.34	5.46	5.56
Electricity	25.23	27.29	28.54	29.73	30.93	32.28	33.87	35.43	37.15	38.95
U.S. Demand (Million Metric Tons)										
Copper	3.34	3.57	3.63	3.67	3.73	3.75	3.88	3.98	4.06	4.13
Iron	145.81	149.79	143.67	146.80	149.39	149.30	151.09	151.94	153.31	154.28
Aluminum	5.81	6.12	6.21	6.43	6.65	6.81	7.05	7.25	7.46	7.66
Recycled Materials (Million Metric Tons)	66.88	69.57	71.29	73.35	75.67	77.54	79.94	81.96	84.00	85.50
Paper/Paperboard	6.38	6.66	7.02	7.26	7.52	7.71	8.00	8.19	8.43	8.62
Aluminum	1.51	1.64	1.66	1.80	1.96	2.14	2.09	2.33	2.45	2.51
Ferrous Metals	38.75	40.15	40.60	41.57	42.61	43.50	44.75	45.76	46.60	47.18

Table 9. (Continued)
General Projections of the Low Productivity Scenario (S3), 1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Total Vehicle Kilometers (Trillions)	1.68	1.71	1.81	1.81	1.84	1.87	1.93	1.96	2.00	2.03
Auto	1.67	1.70	1.79	1.79	1.82	1.85	1.92	1.94	1.98	2.01
Total Freight Metric Ton-Kilometers (Billions)	3.64	3.76	3.85	3.94	4.03	4.14	4.28	4.39	4.52	4.65
Truck	0.75	0.78	0.81	0.85	0.88	0.91	0.96	1.00	1.04	1.08
Rail	1.17	1.20	1.22	1.25	1.27	1.29	1.33	1.36	1.39	1.42
Net Air Residuals (Million Metric Tons)										
Particulates	31.16	32.46	33.09	33.81	34.56	35.05	35.92	36.56	37.31	38.03
Sulfur Oxides	37.51	39.96	40.48	40.85	41.28	41.38	41.99	42.32	43.08	43.80
Nitrogen Oxides	19.11	20.08	20.70	21.02	21.43	21.78	22.42	22.85	23.46	24.03
Hydrocarbons	12.52	12.49	12.76	12.70	12.81	12.94	13.29	13.44	13.72	13.91
Carbon Monoxide	72.65	74.61	77.97	78.68	80.24	81.83	84.77	86.00	88.11	89.54
Net Water Residuals (Million Metric Tons)										
Biochemical Oxygen Demand	4.30	4.45	4.61	4.71	4.84	4.94	5.08	5.17	5.29	5.39
Suspended Solids	9.99	10.28	10.40	10.62	10.86	11.00	11.25	11.41	11.60	11.76
Disolved Solids	12.40	12.61	12.87	12.96	13.07	13.04	13.17	13.15	13.19	13.19
Nutrients	1.19	1.21	1.23	1.25	1.27	1.29	1.32	1.34	1.36	1.38
Incremental Air Control Costs										
Investment[1]	0	0	0	0	0	0	0	0	0	0
Annualized Cost										
Capital[2]	0	0	0	0	0	0	0	0	0	0
O&M	0	0	0	0	0	0	0	0	0	0
Capital in Place	0	0	0	0	0	0	0	0	0	0
Direct Employment	0	0	0	0	0	0	0	0	0	0

Table 9. (Continued)
General Projections of the Low Productivity Scenario (S3), 1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Incremental Water Industrial Costs										
Investment	0	0	0	0	0	0	0	0	0	0
Annualized Costs	0	0	0	0	0	0	0	0	0	0
Capital	0	0	0	0	0	0	0	0	0	0
O&M	0	0	0	0	0	0	0	0	0	0
Capital in Place	0	0	0	0	0	0	0	0	0	0
Direct Employment	0	0	0	0	0	0	0	0	0	0
Incremental Water Municipal Costs										
Investment	0	0	0	0	0	0	0	0	0	0
Annualized Costs	0	0	0	0	0	0	0	0	0	0
Capital	0	0	0	0	0	0	0	0	0	0
O&M	0	0	0	0	0	0	0	0	0	0
Capital in Place	0	0	0	0	0	0	0	0	0	0
Direct Employment	0	0	0	0	0	0	0	0	0	0

[1] Includes state transportation control costs and mobile source pollution abatement expenditures.

[2] Annualized to include interest on all investments, including those for mobile source controls.

The impact of the lower productivity assumptions after 1977 is readily seen: with unemployment rates consistent with those of the Reference Scenario across the decade, considerable reductions in personal consumption expenditures are required in order to maintain full-supply GNP. The historical INFORUM projections of productivity are greater than the actual 1975 factors and are nearly equal to 1977 forecasts for the Reference Scenario. The greatest divergence in forecasts for the two scenarios occurs over the period 1977-80, but significant change continues through 1985. The percentage differences in the personal consumption expenditures for 1980, 1983 and 1985 are -7.8 percent, -11.2 percent and -13.0 percent, respectively. These changes, as well as those prior to 1980, parallel the changes in GNP between the two scenarios. In further comparing results from the two scenarios, the drops in equipment and construction investment are greater than the change in GNP in each, while total output parallels the GNP change. The impact of these economic differences on transportation in the Low Productivity Scenario is significant, with the vehicle kilometers travelled reduced by over 10 percent from 1980 to 1985. The annual reduction in freight-metric-ton-kilometers for the period of 1977-85 is on the order of 1 percent.

The effects of the Low Productivity Scenario on material usage, as measured by U.S. demands for iron, aluminum and copper, follow the economic trends for the period 1980-85, with each demand being down by about 10 percent during the 6-year period. Demands for recycled materials, as typified by aluminum, paper products, and ferrous metals, also are reduced. The decrease in recycled aluminum is 6 percent, only three-fifths of the drop in demand for primary aluminum ore. For recycled paper products, the drop in demand is from 8.3 percent to 12.4 percent over the period 1980-85.

Energy usage also shows significant reductions. Total usage, in quadrillion Btu's, drops from 93.6 to 89.3 in 1980 (4.6 percent drop) and from 109 to 102 (6.4 percent drop) in 1985 between the Reference Scenario and the Low Productivity Scenario. For the Low Productivity scenario, the contributions of coal and nuclear fuels for electric power generation by electric utilities are about equal, with each providing 32 percent of the source energy. Thus, although energy demand decreases from the Reference Scenario, the change is only about half that of the relative decrease in the growth of the economy and other material resources.

The impact on the air and water environmental residuals from the Low Productivity Scenario follows the changes in economic indicators for most listed residuals. Table 11

Table 10.
Comparison of the Macro-Statistics of the Low Productivity Scenario (S3) and the Reference Scenario (S1)
[(S3-S1)/S1 in %]

Statistic	1975	1977	1980	1983	1985
Gross National Product	3.98	0.28	-8.39	-10.39	-11.68
Disposable Income Per Capita	7.28	0.97	-10.39	-14.31	-16.43
Total Employment	-0.01	-0.04	-0.11	-0.20	-0.10
Federal Expenditures	0.0	0.0	0.0	0.0	0.0
Personal Consumption Expenditures	4.61	0.95	-7.77	-11.18	-12.98
Total Output	3.85	0.15	-8.53	-10.30	-11.51
Investment	2.65	-1.50	-13.47	-12.78	-12.78
Energy Use	2.10	0.19	-4.65	-5.70	-6.39
Demand: Iron	3.15	-0.67	-10.78	-10.23	-10.69
Aluminum	2.80	-0.35	-9.88	-9.97	-10.60
Recycling: Paper/Paperboard	4.52	0.57	-8.29	-10.85	-12.38
Aluminum	1.79	-0.17	-5.88	-5.77	-6.19
Ferrous Metals	1.61	-0.31	-5.30	-5.22	-5.53
Vehicle Kilometers Travelled	7.27	0.60	-10.24	-14.47	-16.12
Freight Metric Ton-Kilometers	3.09	0.00	-7.36	-8.54	-9.36
Net Air Residuals:					
Particulates	3.18	0.09	-7.63	-8.50	-9.45
Sulfur Oxides	2.49	0.23	-6.45	-8.49	-9.58
Nitrogen Oxides	4.01	0.41	-7.54	-10.02	-11.51
Hydrocarbons	5.41	0.53	-8.61	-11.23	-12.76
Carbon Monoxide	6.43	0.70	-10.05	-13.43	-15.31
Net Water Residuals:					
Biochemical Oxygen Demand	2.77	0.07	-5.55	-6.76	-7.63
Suspended Solids	2.70	-0.26	-7.72	-8.05	-8.75
Dissolved Solids	4.14	0.28	-8.19	-10.29	-11.73
Nutrients	0.30	-0.01	-0.67	-0.78	-0.88

shows the relative levels of net residuals, with stationary and mobile air residual emissions reported separately.

Table 11.
Environmental Residuals from Low Productivity Scenario (S3) as a Percentage of Reference Scenario Residuals (S1)
(S3/S1 in %)

	1977	1980	1983	1985
Air Residuals Stationary Sources				
Particulates	100	92	92	91
Sulfur Oxides	100	94	92	90
Nitrogen Oxides	100	94	92	90
Hydrocarbons	100	93	92	91
Carbon Monoxide	99	91	91	90
Air Residuals Mobile Sources				
Particulates	100	92	92	91
Sulfur Oxides	100	93	92	90
Nitrogen Oxides	100	91	90	88
Hydrocarbons	101	91	89	87
Carbon Monoxide	101	90	87	85
Water Residuals				
Biochemical Oxygen Demand	100	94	93	92
Suspended Solids	100	92	92	91
Dissolved Solids	100	92	90	88
Nutrients	100	99	99	99

The second scenario which assumes different economic conditions, the Low Productivity Abatement Scenario, differs from its baseline, the Low Productivity Scenario, in the same fashion as the Abatement Scenario differs from the Reference Scenario. Thus, a comparison of the statistics of the Low Productivity Abatement Scenario with those of the Low Productivity Scenario provides an impact analysis of Federal pollution control laws and regulations, given the low growth economic conditions.

Table 12 provides the general statistics for the Low Productivity Abatement Scenario in a form comparable to that used for the Reference Abatement Scenario in Table 4. The general comparative economic trends found for the Reference Abatement Scenario continue for this scenario, with the stimulus to economic output due to compliance with Federal pollution control laws and regulations in evidence throughout the decade, as shown in Table 13. Through 1980, there is sufficiently high unemployment in the Low Productivity Scenario so that the additional labor force required for abatement is available. After that time, however, small diversions of labor from competing sources of employment are required.

Table 12.
General Projections of the Low Productivity Abatement Scenario (S4),
1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Population (Millions)	215.80	217.70	219.80	221.90	224.10	226.40	228.70	231.00	233.40	235.70
Labor Force (Millions)	95.40	97.00	98.60	100.20	101.80	103.20	104.50	105.70	106.70	107.70
Unemployment Rate (%)	6.50	5.40	4.60	4.40	4.50	4.40	4.30	4.30	4.30	4.20
Disposable Income										
Per Capita (1,000 1975 $)	5.91	6.13	6.49	6.61	6.75	6.92	7.03	7.12	7.21	7.29
Gross National Product										
(Trillion 1975 $)	1.65	1.72	1.77	1.81	1.86	1.91	1.96	2.00	2.04	2.09
Personal Consumption										
Expenditures	1.01	1.05	1.11	1.14	1.18	1.22	1.26	1.29	1.32	1.36
Investment	0.29	0.30	0.29	0.30	0.31	0.31	0.32	0.32	0.32	0.33
Government Expenditures	0.33	0.34	0.35	0.35	0.36	0.36	0.37	0.38	0.39	0.39
Federal	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.14	0.14
Other	0.21	0.22	0.23	0.23	0.23	0.24	0.24	0.25	0.25	0.26
Total Output										
(Trillion 1975 $)	2.76	2.89	2.98	3.07	3.16	3.26	3.35	3.43	3.52	3.61
Total Energy Use										
(Quadrillion Btu's)	84.59	87.19	88.98	90.74	92.44	95.07	97.66	100.32	103.28	106.21
Natural Gas	20.11	19.75	19.83	19.85	19.87	20.01	20.11	20.20	20.36	20.46
Petroleum	33.35	33.81	34.22	34.69	35.10	35.95	36.76	37.54	38.35	39.13
Coal	4.90	5.16	5.11	5.11	5.14	5.25	5.33	5.43	5.52	5.62
Electricity	26.16	28.47	29.83	31.08	32.33	33.86	35.46	37.15	39.05	41.00
U.S. Demand										
(Million Metric Tons)										
Copper	3.51	3.76	3.77	3.76	3.78	3.83	3.94	4.02	4.06	4.13
Iron	152.22	157.03	150.18	149.48	149.56	150.42	150.14	150.66	150.76	151.56
Aluminum	6.04	6.40	6.41	6.55	6.72	6.91	7.10	7.28	7.44	7.63
Recycled Materials										
(Million Metric Tons)	68.23	71.03	72.36	74.05	76.01	78.25	80.15	82.26	84.05	85.68
Paper/Paperboard	6.47	6.77	7.09	7.31	7.53	7.78	8.00	8.20	8.40	8.60
Aluminum	1.54	1.68	1.69	1.82	1.98	2.16	2.10	2.34	2.45	2.52
Ferrous Metals	39.56	41.03	41.31	42.01	42.85	43.87	44.93	45.96	46.72	47.35

Table 12. (Continued)
General Projections of the Low Productivity Abatement Scenario (S4), 1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	
Total Vehicle Kilometers											
(Trillions)	1.70	1.74	1.81	1.82	1.83	1.89	1.92	1.95	1.98	2.01	
Auto	1.69	1.72	1.80	1.80	1.82	1.87	1.91	1.94	1.97	2.00	
Total Freight Metric Ton-Kilometers											
(Billions)	3.77	3.91	3.98	4.05	4.12	4.25	4.37	4.49	4.61	4.74	
Truck	0.78	0.82	0.84	0.87	0.90	0.94	0.98	1.02	1.06	1.11	
Rail	1.22	1.25	1.27	1.28	1.30	1.33	1.36	1.39	1.42	1.45	
Net Air Residuals (Million Metric Tons)											
Particulates	13.18	8.33	8.35	8.35	8.44	8.59	7.81	7.00	6.13	5.27	
Sulfur Oxides	19.87	14.77	15.07	15.30	15.53	15.82	16.00	16.20	16.48	16.77	
Nitrogen Oxides	19.21	20.08	20.46	20.52	20.62	20.88	21.28	21.58	21.83	22.16	
Hydrocarbons	10.49	9.65	9.27	8.71	8.24	7.90	7.29	6.67	6.14	5.61	
Carbon Monoxide	58.55	53.68	49.76	44.54	39.85	35.85	31.09	28.19	23.99	21.44	
Net Water Residuals (Million Metric Tons)											
Biochemical Oxygen Demand	3.24	2.77	2.24	2.17	2.10	1.92	1.72	1.51	1.29	1.19	
Suspended Solids	6.70	4.87	2.82	2.77	2.73	2.40	2.04	1.67	1.29	1.21	
Dissolved Solids	11.91	11.65	11.36	11.38	11.40	10.47	9.58	8.76	8.05	8.23	
Nutrients	1.14	1.14	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	
Incremental Air Control Costs (Billion 1975 $)											
Investment[1]	8.28	9.06	9.91	6.53	6.37	6.54	6.68	6.78	6.76	6.66	
Annualized Costs											
Capital[2]	7.54	8.80	11.04	12.76	14.31	15.61	16.69	17.53	18.12	18.46	
O&M	8.80	8.25	8.20	8.90	9.43	9.84	10.28	10.70	11.11	11.50	
Capital in Place	39.90	46.21	54.91	60.34	64.81	68.60	71.83	74.46	76.41	77.57	
Direct Employment (Thousands)	15	17	19	20	20	20	19	19	19	18	

Table 12. (Continued)
General Projections of the Low Productivity Abatement Scenario (S4), 1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Incremental										
Water Industrial Costs										
(Billion 1975 $)										
Investment	4.31	6.27	3.38	2.55	4.37	4.42	5.91	5.46	1.53	1.19
Annualized Costs										
Capital	2.06	2.89	3.32	3.65	4.22	4.79	5.56	6.27	6.45	6.59
O&M	3.75	5.03	5.76	5.95	6.12	6.34	6.59	6.85	9.95	10.29
Capital in Place	15.69	21.95	25.27	27.76	32.07	36.43	42.27	47.67	49.06	50.12
Direct Employment (Thousands)	117	157	180	186	192	199	206	215	328	339
Incremental										
Water Municipal Costs										
(Billion 1975 $)										
Investment	6.55	8.11	8.13	5.59	2.94	1.77	0.80	0.70	0.70	0.53
Annualized Costs										
Capital	2.28	3.18	4.07	4.69	5.01	5.21	5.30	5.37	5.45	5.51
O&M	0.68	0.93	1.36	1.61	1.76	1.84	1.89	1.93	1.97	2.00
Capital in Place	20.74	28.85	36.99	42.57	45.51	47.28	48.08	48.78	49.48	50.01
Direct Employment (Thousands)	20	28	40	48	52	54	56	57	58	59

[1] Includes state transportation control costs and mobile source pollution abatement expenditures.

[2] Annualized to include interest on all investments, including those for mobile source controls.

Table 13.
Comparison of the Macro-Statistics of the Low Productivity Abatement Scenario (S4) and the Low Productivity Scenario (S3)
[(S4-S3)/S3 in %]

Statistic	1975	1977	1980	1983	1985
Gross National Product	1.89	2.76	0.79	0.60	0.06
Disposable Income Per Capita	0.07	1.29	-0.18	-0.06	-0.63
Total Employment	0.94	1.83	0.67	0.44	0.21
Federal Expenditures	0.23	1.07	2.22	2.20	2.15
Personal Consumption Expenditures	0.56	1.16	0.13	0.18	-0.16
Total Output	2.24	3.11	1.07	0.85	0.39
Investment	6.99	7.45	2.46	1.41	-0.32
Energy Use	3.76	4.22	3.57	3.78	4.08
Demand: Iron	3.86	4.83	0.12	-0.84	-1.77
Aluminum	3.27	4.41	1.06	0.52	-0.29
Recycling: Paper/Paperboard	0.68	1.65	0.17	0.08	-0.24
Aluminum	2.03	2.65	0.57	0.39	0.07
Ferrous Metals	1.66	2.20	0.35	0.42	0.37
Vehicle Kilometers Travelled	0.07	1.29	-0.98	-0.06	-0.63
Freight Metric Ton-Kilometers	3.49	4.00	2.25	2.28	2.16
Net Air Residuals:					
Particulates	-41.74	-67.07	-77.58	-80.85	-86.15
Sulfur Oxides	-31.87	-63.03	-62.37	-61.71	-61.72
Nitrogen Oxides	0.00	-0.03	-3.81	-5.57	-7.78
Hydrocarbons	-13.63	-22.71	-35.66	-50.41	-59.68
Carbon Monoxide	-18.96	-28.06	-50.34	-67.22	-76.06
Net Water Residuals:					
Biochemical Oxygen Demand	-11.81	-37.72	-56.54	-70.72	-77.80
Suspended Solids	-14.24	-52.62	-74.83	-85.36	-89.69
Dissolved Solids	-0.97	-7.54	-12.77	-33.39	-37.65
Nutrients	-1.97	-6.16	-11.80	-16.38	-19.20

The relative impact of pollution control expenditures for the Low Productivity Abatement Scenario are shown in Table 14, which presents these costs as a percentage of the Low Productivity Scenario GNP. These proportions can be compared with similar data for the Reference Case given in Table 6.

Table 14.
Incremental Pollution Control Costs as a Percentage of Low Productivity Scenario GNP

	1977	1980	1983	1985	1976-85
Air Stationary Source Costs					
Annual Capital Cost	0.29	0.34	0.31	0.31	0.30
O&M Cost	0.26	0.29	0.26	0.25	0.27
Water Industrial Costs					
Annual Capital Cost	0.17	0.23	0.31	0.32	0.24
O&M Cost	0.29	0.33	0.34	0.49	0.35
Water Municipal Costs					
Annual Capital Cost	0.19	0.29	0.27	0.26	0.25
O&M Cost	0.05	0.10	0.10	0.10	0.08

Comparing the statistics of Tables 6 and 14 demonstrates that the relative level of impact at the macroeconomic level is similar for the two cases. Hence, over the range of economic growth bounded by these situations, the level of direct economic impact of pollution control legislation appears to be reasonably constant. The indirect impacts also are similar in terms of increased employment levels for each abatement scenario as compared to its non-abatement scenario.

Tables 15 and 16 provide aggregate pollutant treatment projections for the Low Productivity Abatement Scenario that are comparable to the Reference Abatement Scenario values of Tables 7 and 8. As can be noted, the treatment efficiencies are comparable, with consistent trends for all residuals. This suggests that the level of economic output has no major effect on aggregate treatment levels.

In a similar vein, the changes in material and energy usage between the non-abatement and the abatement scenarios are similar to the economic patterns for each case. Thus, in terms of macroeconomic impacts, the introduction of Federally imposed pollution controls produces comparable effects for the high economic growth Reference Abatement Scenario and the low economic growth Low Productivity Abatement Scenario.

Table 15.
Relative Stationary Source Treatment Efficiences of Selected Pollutants for the Low Productivity and Low Productivity Abatement Scenarios (Efficiencies in Percent of Residuals Removed)

	1975		1980		1985		
	Low Productivity	Low Productivity Abatement	Low Productivity	Low Productivity Abatement	Low Productivity	Low Productivity Abatement	Productivity
Air Residuals							
Particulates	73.6	85.3	74.2	94.1	73.8	97.0	
Sulfur Oxides	23.8	51.1	24.0	73.0	23.9	72.5	
Nitrogen Oxides	0.2	2.5	0.2	5.6	0.3	5.7	
Hydrocarbons	39.3	50.6	40.3	59.5	42.3	71.2	
Carbon Monoxide	46.6	62.3	47.3	73.5	48.6	76.8	
Water Residuals							
Biochemical Oxygen Demand	68.4	72.4	68.0	86.1	67.9	92.9	
Suspended Solids	82.8	85.8	83.2	96.0	83.7	98.4	
Dissolved Solids	31.0	33.7	32.5	43.7	35.0	61.4	
Nutrients	35.9	37.8	37.8	46.3	39.2	52.3	

Table 16.
Passenger Transportation Emission Levels for the Low Productivity and Low Productivity Abatement Scenarios
(Metric Tons per Million Vehicle Kilometers Travelled)

	1975		1980	1985			
	Low Productivity	Low Productivity Abatement	Low Productivity	Low Productivity Abatement	Low Productivity	Low Productivity Abatement	Productivity
Air Residuals							
Particulates	0.22	0.18	0.21	0.16	0.21	0.14	
Sulfur Oxides	0.08	0.08	0.08	0.08	0.08	0.08	
Nitrogen Oxides	1.94	1.82	1.92	1.60	1.91	1.11	
Hydrocarbons	2.65	2.28	2.21	1.25	2.13	0.53	
Carbon Monoxide	22.05	17.92	22.29	10.48	22.48	3.65	

COMPARATIVE ANALYSIS FOR THE ENERGY CONSERVATION SCENARIOS

To further explore the possible variations in pollution control costs because of different assumptions about conditions and policies in the future, a pair of scenarios was constructed which approximated energy usage forecasts in the Federal Energy Administration's "Business-as-Usual-With-Conservation" scenario, where the price of imported oil is $11 per barrel. In this analysis, it was assumed that this reduction in energy use could be achieved by the following actions:

1. Reduced household energy consumption for space-heating and cooling by using improved insulation and higher summer and lower winter thermostat settings.

2. Reduced per capita gasoline use through increased carpooling, increased use of mass transit, and improved auto fuel consumption efficiency.

3. A reduction in the interindustry fossil fuel use coefficients (energy input required to produce one unit of output) for energy-intensive products by substitution of less energy-intensive inputs. These reductions include: shifts to returnable beverage containers, reductions in the use of artificial fertilizers, reduced use of packaging materials, and some recycling of energy-intensive materials.

4. Miscellaneous changes to reflect improved energy housekeeping activities in certain industries.

The first of the Energy Conservation scenarios, without the Federally imposed pollution controls, is denoted as the Energy Scenario. The second, which introduces the effects of pollution control in the same way as for the other two abatement scenarios, is the Energy Abatement Scenario.

A set of output statistics for the Energy Scenario is provided in Table 17. Some of the major economic factors are compared to Reference Scenario values in Table 18. The differences which occur are present even though the primary factors that alter GNP, the final demand accounts of personal consumption expenditures and Federal expenditures, were held at the same levels for the Reference and the Energy Scenarios (and also were held constant for the Reference Abatement and Energy Abatement Scenarios). Thus, the impacts are solely a result of purchase changes due to energy conservation measures introduced in the Energy Conservation case.

Table 17.
General Projections of the Energy Scenario (S5), 1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Population (Millions)	215.80	217.70	219.80	221.90	224.30	226.40	228.70	231.00	233.40	235.70
Labor Force (Millions)	95.40	97.00	98.60	100.20	101.80	103.20	104.50	105.70	106.70	107.70
Unemployment Rate (%)	7.90	6.90	5.80	5.20	4.70	5.10	4.60	4.40	4.30	4.20
Disposable Income Per Capita (1,000 1975 $)	5.62	5.99	6.61	7.04	7.54	7.74	8.07	8.31	8.53	8.78
Gross National Product (Trillion 1975 $)	1.56	1.67	1.78	1.90	2.02	2.08	2.16	2.23	2.30	2.37
Personal Consumption Expenditures	0.97	1.03	1.12	1.19	1.28	1.33	1.39	1.45	1.51	1.56
Investment	0.26	0.29	0.29	0.32	0.35	0.35	0.36	0.36	0.37	0.38
Government Expenditures	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.41
Federal	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.14
Other	0.20	0.21	0.22	0.23	0.24	0.25	0.25	0.26	0.27	0.27
Total Output (Trillion 1975 $)	2.61	2.81	3.00	3.21	3.43	3.54	3.67	3.80	3.93	4.05
Total Energy Use (Quadrillion Btu's)	76.55	79.36	81.66	84.26	86.80	88.47	90.31	92.14	94.00	95.70
Natural Gas	18.81	18.70	19.07	19.43	19.79	19.88	20.06	20.21	20.39	20.53
Petroleum	28.70	29.24	29.67	30.18	30.61	30.81	31.02	31.24	31.44	31.57
Coal	4.59	4.89	4.99	5.24	5.48	5.57	5.66	5.76	5.88	6.00
Electricity	24.45	26.53	27.93	29.40	30.91	32.21	33.58	34.93	36.30	37.61
U.S. Demand (Million Metric Tons)										
Copper	3.18	3.53	3.72	3.92	4.12	4.17	4.25	4.33	4.41	4.47
Iron	141.37	150.67	149.67	159.22	167.68	167.16	166.23	166.54	167.33	168.34
Aluminum	5.65	6.16	6.44	6.92	7.41	7.56	7.69	7.86	8.04	8.22
Recycled Materials (Million Metric Tons)	65.78	69.83	72.93	76.97	81.22	82.16	85.32	87.66	89.73	91.52
Paper/Paperboard	6.19	6.64	7.18	7.69	8.23	8.52	8.88	9.21	9.54	9.87
Aluminum	1.48	1.64	1.70	1.88	2.09	2.27	2.19	2.41	2.52	2.57
Ferrous Metals	38.25	40.31	41.41	43.23	45.10	45.98	46.93	47.88	48.60	49.17

Table 17. (Continued)
General Projections of the Energy Scenario (S5),
1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Total Vehicle Kilometers (Trillions)	1.49	1.54	1.66	1.73	1.82	1.86	1.93	1.99	2.03	2.08
Auto	1.47	1.53	1.64	1.71	1.80	1.83	1.90	1.96	2.00	2.05
Total Freight Metric Ton-Kilometers (Billions)	3.52	3.77	3.94	4.16	4.39	4.50	4.64	4.79	4.93	5.08
Truck	0.73	0.79	0.84	0.90	0.96	1.00	1.04	1.09	1.14	1.19
Rail	1.14	1.21	1.26	1.32	1.38	1.41	1.45	1.48	1.52	1.56
Net Air Residuals (Million Metric Tons)										
Particulates	30.09	32.11	33.49	34.37	36.93	37.50	37.21	37.93	39.73	40.50
Sulfur Oxides	35.79	38.66	39.76	41.01	42.32	42.39	42.65	42.92	43.24	43.50
Nitrogen Oxides	18.04	19.32	20.30	21.21	22.21	22.63	23.26	23.80	24.36	24.93
Hydrocarbons	11.30	11.49	11.94	12.24	12.66	12.76	13.07	13.29	13.52	13.76
Carbon Monoxide	64.65	67.73	72.33	75.77	79.75	81.56	84.61	86.86	88.89	91.23
Net Water Residuals (Million Metric Tons)										
Biochemical Oxygen Demand	4.23	4.45	4.69	4.90	5.14	5.25	5.40	5.53	5.67	5.81
Suspended Solids	9.77	10.31	10.69	11.23	11.79	11.95	12.14	12.34	12.55	12.76
Dissolved Solids	11.99	12.47	13.04	13.57	14.10	14.14	14.26	14.35	14.41	14.45
Nutrients	1.19	1.21	1.23	1.26	1.28	1.30	1.33	1.35	1.37	1.40

Table 17. (Continued)
General Projections of the Energy Scenario (S5), 1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Incremental Air Control Costs (Billion 1975$)										
Investment[1]	0	0	0	0	0	0	0	0	0	0
Annualized Costs	0	0	0	0	0	0	0	0	0	0
Capital[2]	0	0	0	0	0	0	0	0	0	0
O&M	0	0	0	0	0	0	0	0	0	0
Capital in Place	0	0	0	0	0	0	0	0	0	0
Direct Employment (Thousands)	0	0	0	0	0	0	0	0	0	0
Incremental Water Industrial Costs (Billion 1975 $)										
Investment	0	0	0	0	0	0	0	0	0	0
Annualized Costs	0	0	0	0	0	0	0	0	0	0
Capital	0	0	0	0	0	0	0	0	0	0
O&M	0	0	0	0	0	0	0	0	0	0
Capital in Place	0	0	0	0	0	0	0	0	0	0
Direct Employment (Thousands)	0	0	0	0	0	0	0	0	0	0
Incremental Water Municipal Costs (Billion 1975 $)										
Investment	0	0	0	0	0	0	0	0	0	0
Annualized Costs	0	0	0	0	0	0	0	0	0	0
Capital	0	0	0	0	0	0	0	0	0	0
O&M	0	0	0	0	0	0	0	0	0	0
Capital in Place	0	0	0	0	0	0	0	0	0	0
Direct Employment (Thousands)	0	0	0	0	0	0	0	0	0	0

[1] Includes state transporation control costs and mobile source pollution abatement expenditures.

[2] Annualized to include interest on all investments, including those for mobile source controls.

Table 18.
Summary of Major Economic
Factors of the Energy Scenario
as Compared to the Reference Scenario

	1975	1977	1980	1983	1985
GNP (Billion 1975 $)					
Energy	1,470	1,669	2,020	2,227	2,370
Reference	1,470	1,665	2,012	2,221	2,365
Difference	0	+4	+8	+6	+5
Employment (Millions)					
Energy	86.1	90.4	97.1	101.1	103.2
Reference	86.1	90.3	96.8	100.9	103.1
Difference	0	+0.1	+0.3	+0.2	+0.1
Investment (Billion 1975 $)					
Energy	221	285	345	362	377
Reference	221	286	344	364	381
Difference	0	-1	1	-2	-4
Net Exports (Billion 1975 $)					
Energy	10.5	11.3	8.6	6.2	1.2
Reference	10.6	7.7	1.6	-2.6	-8.9
Difference	-0.1	3.6	7.0	8.8	10.1

It can be seen that the major factor in raising GNP between the Energy Scenario and the Reference Scenario is increased net exports and that, for several years, the level of investment expenditures actually declines slightly. To achieve increased net exports, both imports and exports fall, with imports decreasing at a faster rate. Turning to total output, for most years the output of the Energy Scenario is about 0.1 to 0.3 percent higher than the Reference Scenario; however, the pattern is erratic. This induces similar increases in employment, as shown in Table 18.

To analyze changes in energy and material consumption between the two scenarios, Table 19 provides annual usage comparisons for petroleum, coal, electricity, iron ore, aluminum, and copper. (Note that petroleum and coal data in

Table 19 include use in generating electricity. Table 17 figures do not include this factor in order to avoid double-counting in energy accounting.) The trends for usage of these forms of energy and materials are consistant with the variations in assumptions for the scenarios. Petroleum demand, coal demand, and electricity demand for the Energy Scenario decline in 1985 by approximately 21, 11, and 8.5 percent, respectively, when compared to the Reference Scenario. Slight decreases in use of iron, aluminum and copper are noted with no decline greater than 5 percent, which is consistent with the variation in total output.

Table 19.
Comparison of Energy & Material Usage Between the Reference and Energy Scenarios

	1975	1977	1980	1983	1985
Petroleum (Btu's Quadrillions)					
Energy	32.1	33.8	36.1	37.2	37.9
Reference	34.3	37.2	41.4	45.0	47.6
Difference	-2.2	-3.4	-5.3	-7.8	-9.7
Coal (Btu's Quardrillions)					
Energy	13.8	16.6	17.7	17.6	17.6
Reference	13.9	17.0	18.4	19.0	19.8
Difference	-0.1	-0.4	-0.7	-1.4	-2.2
Electricity (Btu's Quadrillions)					
Energy	22.5	26.5	30.9	34.9	37.6
Reference	22.8	27.3	32.1	37.1	41.1
Difference	-0.3	-0.8	-1.2	-2.2	-3.5
Iron Ore (Million Metric Tons)					
Energy	129	151	168	167	168
Reference	129	151	167	169	173
Difference	0	0	-1	-2	-5
Aluminum (Million Metric Tons)					
Energy	5.1	6.2	7.4	7.9	8.2
Reference	5.1	6.2	7.4	8.0	8.6
Difference	0	0	0	-0.1	-0.4
Copper (Million Metric Tons)					
Energy	2.9	3.5	4.1	4.3	4.5
Reference	2.9	3.5	4.1	4.4	4.5
Difference	0	0	0	-0.1	0

As a final comparison of the effects of energy conservation, Table 20 provides the level of environmental residuals produced in the Energy Scenario relative to those produced in the Reference Scenario.

Table 20.
Environmental Residuals from Energy Scenario (S5)
as a Percentage of Reference Scenario Residuals (S1)
(S5/S1 in %)

Air Residuals	1975	1977	1980	1983	1985
Air Residuals Stationary Sources					
Particulates	99	99	99	98	96
Sulfur Oxides	98	97	96	93	89
Nitrogen Oxides	98	97	96	93	89
Hydrocarbons	95	95	92	89	87
Carbon Monoxide	98	99	98	96	95
Air Residuals Mobile Sources					
Particulates	95	95	95	94	95
Sulfur Oxides	98	101	103	104	105
Nitrogen Oxides	95	96	96	95	94
Hydrocarbons	92	91	89	87	86
Carbon Monoxide	92	90	88	86	85
Water Residuals					
Biochemical Oxygen Demand	100	100	100	100	99
Suspended Solids	100	100	100	99	99
Dissolved Solids	100	99	99	98	97
Nutrients	100	100	100	100	100

In general, for water residuals, little impact is noted since the energy conservation assumptions do not cause major variations in output for the industries that produce the majority of water pollutants. The reduction in mobile source emissions is consistent with the major reduction in auto mileage and concomitant small increases in mass transit and small decreases in freight transportation.

The major impact of the Energy Scenario on residuals is in stationary source air emissions. All five air residuals, particulates, sulfur oxides, nitrogen oxides, hydrocarbons, and carbon monoxide, show significantly lower levels over time. The lesser reductions for particulates and carbon monoxide are due to a mixed reaction in the output levels of six major producing sectors.

In summary, the Energy Conservation Scenario assumptions produce major effects on energy and material consumption and on air pollution emissions when compared to the Reference Scenario. Remaining statistics for the two scenarios show only minor effects when the two are compared.

The effects of the pollution control regulations under the Energy Conservation Case assumptions are provided by comparing the Energy Abatement Scenario with its predecessor, the Energy Scenario. The general output statistics for the Energy Abatement Scenario are given in Table 21 while Table 22 compares the results of Energy Abatement Scenario with those of the Energy Scenario. As in the other scenario pairs, the scenario that includes the pollution control costs and purchases generates higher employment, GNP and total output for all forecast years. The differences are greatest for the years 1975 and 1977 when the available labor force is sufficient to provide for the increased resources needed for abatement controls without diverting labor from competing employment opportunities. By 1985, Energy Abatement Scenario forecasts are greater than those of the Energy Scenario by 0.16 percent for GNP, 0.54 percent for total output and 0.26 percent for total employment.

Table 23 presents various pollution control costs as a percentage of Energy Scenario GNP. Comparing these percentages with the values given in Table 6 and Table 14 again reveals the relative impact insensitivity over the range of assumptions provided in this macroeconomic/energy analysis.

Table 21.
General Projections of the Energy Abatement Scenario (S6), 1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Population (Millions)	215.80	217.70	219.80	227.19	224.20	226.40	228.70	231.00	233.40	235.70
Labor Force (Millions)	95.40	97.00	98.60	100.20	101.80	103.20	104.50	105.70	106.70	107.70
Unemployment Rate (%)	6.30	5.20	4.00	4.10	4.60	4.60	4.50	4.20	4.00	4.00
Disposable Income Per Capita (1,000 1975 $)	5.62	5.99	6.53	7.00	7.46	7.69	8.00	8.25	8.48	8.70
Gross National Product (Trillion 1975 $)	1.59	1.70	1.81	1.91	2.02	2.09	2.16	2.23	2.30	2.37
Personal Consumption Expenditures	0.97	1.03	1.12	1.19	1.27	1.33	1.39	1.45	1.51	1.56
Investment	0.27	0.30	0.30	0.33	0.35	0.36	0.36	0.37	0.37	0.38
Government Expenditures	0.32	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.41	0.42
Federal	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.14	0.14
Other	0.20	0.22	0.23	0.24	0.25	0.25	0.26	0.27	0.27	0.28
Total Output (Trillion 1975 $)	2.66	2.86	3.06	3.24	3.44	3.56	3.68	3.81	3.95	4.08
Total Energy Use (Quadrillion Btu's)	79.42	82.36	85.52	87.40	89.71	91.85	93.69	95.91	98.32	100.39
Natural Gas	19.38	19.31	19.76	20.05	20.34	20.52	20.67	20.90	21.20	21.39
Petroleum	30.00	30.37	30.88	31.21	31.55	31.92	32.14	32.50	32.86	33.11
Coal	4.78	5.12	5.24	5.41	5.57	5.67	5.73	5.84	5.95	6.08
Electricity	25.26	27.57	29.27	30.73	32.25	33.74	35.15	36.67	38.31	39.81
U.S. Demand (Million Metric Tons)										
Copper	3.30	3.67	3.85	4.04	4.18	4.23	4.30	4.37	4.44	4.49
Iron	145.45	155.58	155.71	161.96	166.59	166.43	164.31	164.42	164.80	165.95
Aluminum	5.81	6.34	6.63	7.05	7.44	7.61	7.72	7.88	8.05	8.23
Recycled Materials (Million (Million Metric Tons)	66.59	70.71	73.84	77.46	81.15	83.32	85.26	87.70	89.82	91.89
Paper/Paperboard	6.23	6.68	7.23	7.69	8.18	8.51	8.84	9.19	9.53	9.85
Aluminum	1.51	1.67	1.73	1.90	2.10	2.28	2.20	2.42	2.52	2.57
Ferrous Metals	38.79	40.81	42.04	43.64	45.19	46.12	47.00	47.97	48.72	49.34

Table 21. (Continued)
General Projections of the Energy Abatement Scenario (S6), 1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Total Vehicle Kilometers (Trillions)	1.49	1.54	1.64	1.72	1.80	1.85	1.92	1.97	2.01	2.06
Auto	1.47	1.53	1.62	1.70	1.78	1.82	1.89	1.94	1.98	2.02
Total Freight Metric Ton-Kilometers (Billions)	3.63	3.89	4.07	4.26	4.45	4.58	4.71	4.87	5.03	5.19
Truck	0.75	0.81	0.87	0.92	0.97	1.02	1.06	1.11	1.16	1.21
Rail	1.17	1.25	1.30	1.35	1.40	1.44	1.47	1.51	1.55	1.59
Net Air Residuals (Million Metric Tons)										
Particulates	12.56	8.13	8.45	8.74	9.03	9.19	8.33	7.49	6.59	5.67
Sulfur Oxides	18.82	14.16	14.82	15.36	15.94	16.23	16.38	16.60	16.86	17.05
Nitrogen Oxides	18.01	19.18	20.05	20.66	21.30	21.59	22.06	22.46	22.75	23.04
Hydrocarbons	9.41	8.76	8.58	8.31	8.06	7.69	7.13	6.56	6.07	5.58
Carbon Monoxide	51.43	48.12	45.69	42.80	39.79	35.89	31.65	28.41	25.05	22.70
Net Water Residuals (Million Metric Tons)										
Biochemical Oxygen Demand	3.18	2.76	2.26	2.23	2.20	2.00	1.80	1.59	1.37	1.27
Suspended Solids	6.50	4.84	2.86	2.88	2.89	2.52	2.15	1.75	1.33	1.26
Dissolved Solids	11.41	11.40	11.45	11.79	12.14	11.17	10.25	9.44	8.70	8.90
Nutrients	1.14	1.14	1.12	1.12	1.13	1.13	1.13	1.12	1.12	1.12
Incremental Air Control Costs (Billion 1975 $)										
Investment[1]	6.31	8.40	10.82	8.18	7.12	7.04	6.76	6.69	6.66	6.85
Annualized Costs										
Capital[2]	7.31	8.58	10.96	12.83	14.48	15.85	16.93	17.76	18.34	18.70
O&M	8.72	8.09	8.11	8.97	9.67	10.20	10.62	11.03	11.45	11.89
Capital in Place	37.48	44.14	53.75	60.82	66.04	70.34	73.65	76.19	78.04	79.40
Direct Employment (Thousands)	14	17	18	20	21	21	21	20	20	19

Table 21. (Continued)
General Projections of the Energy Abatement Scenario (S6), 1976-1985

Statistics	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Incremental Water Industrial Costs (Billion 1975 $)										
Investment	3.47	5.62	3.24	5.15	6.40	5.60	6.65	5.18	1.30	1.53
Annualized Costs										
Capital	1.97	2.71	3.13	3.80	4.63	5.36	6.22	6.90	7.05	7.24
O&M	3.63	4.89	5.85	6.32	6.71	7.04	7.24	7.51	10.67	11.10
Capital in Place	14.99	20.60	23.78	28.87	35.21	40.75	47.35	52.46	53.63	55.03
Direct Employment (Thousands)	114	150	183	198	210	220	227	235	350	365
Incremental Water Municipal Costs (Billion 1975 $)										
Investment	6.55	8.11	8.13	5.59	2.94	1.77	0.80	0.70	0.70	0.53
Annualized Costs										
Capital	2.28	3.18	4.07	4.69	5.01	5.21	5.30	5.37	5.45	5.51
O&M	0.68	0.93	1.36	1.61	1.76	1.84	1.89	1.93	1.97	2.00
Capital in Place	20.74	28.85	36.99	42.57	45.51	47.28	48.08	48.78	49.48	50.01
Direct Employment (Thousands)	20	28	40	48	52	54	56	57	58	59

[1] Includes state transportation control costs and mobile source pollution abatement expenditures.

[2] Annualized to include interest on all investments, including those for mobile source controls.

Table 22.
Comparison of the Macro Statistics of the Energy Abatement Scenario (S6) and the Energy Scenario (S5)
[(S6-S5)/S5 in %]

Statistic	1975	1977	1980	1983	1985
Gross National Product	1.97	1.74	0.10	0.22	0.16
Disposable Income Per Capita	0.00	0.00	-0.95	-0.82	-1.19
Total Employment	2.04	1.86	0.14	0.26	0.26
Federal Expenditures	0.24	1.07	2.24	2.20	2.17
Personal Consumption Expenditures	0.59	0.33	-0.70	-0.22	-0.12
Total Output	2.33	2.07	0.34	0.50	0.54
Investment	6.11	5.24	1.79	0.94	0.38
Energy Use	3.98	3.78	3.35	4.09	4.89
Demand: Iron	3.99	3.26	-0.65	-1.27	-1.42
Aluminum	3.42	3.02	0.48	0.30	0.19
Recycling: Paper/Paperboard	0.71	0.68	-0.64	-0.25	-0.15
Aluminum	2.13	1.18	0.22	0.22	0.21
Ferrous Metals	1.70	1.46	0.19	0.18	0.35
Vehicle Kilometers Travelled	0.00	0.00	-0.95	-0.82	-1.23
Freight Metric Ton-Kilometers	3.60	3.05	1.88	1.80	2.13
Net Air Residuals:					
Particulates	-41.19	-74.69	-75.54	-80.25	-86.00
Sulfur Oxides	-32.67	-63.40	-62.34	-61.32	-60.81
Nitrogen Oxides	-1.63	-2.00	-4.12	-7.80	-7.61
Hydrocarbons	-13.37	-23.93	-36.35	-50.69	-59.48
Carbon Monoxide	-19.05	-29.14	-50.11	-67.29	-75.12
Net Water Residuals:					
Biochemical Oxygen Demand	-11.70	-38.05	-57.26	-71.25	-78.07
Suspended Solids	-14.15	-53.07	-75.46	-85.83	-90.11
Dissolved Solids	-0.85	-8.61	-13.88	-34.22	-38.38
Nutrients	-1.96	-6.20	-11.99	-16.62	-19.45

Table 23.
Incremental Pollution Control Costs as a Percentage of Energy Scenario GNP

	1977	1980	1983	1985	1976-85
Air Stationary Source Costs					
Annual Capital Cost	0.28	0.30	0.29	0.28	0.29
O&M Cost	0.26	0.28	0.25	0.24	0.26
Water Industrial Costs					
Annual Capital Cost	0.16	0.23	0.31	0.30	0.24
O&M Cost	0.28	0.33	0.34	0.47	0.35
Water Municipal Costss					
Annual Capital Cost	0.19	0.25	0.24	0.23	0.22
O&M Cost	0.05	0.09	0.09	0.08	0.07

The effects of the energy conservation assumptions on environmental residuals are provided as annual average treatment efficiencies and emission levels in Tables 24 and 25. These values again show about the same changes in treatment efficiencies, although the changes are slightly different here than in the Reference Abatement and Low Productivity Abatement Scenarios. This difference results primarily from the greater variability introduced into the interindustry flows by the energy conservation measures.

Thus, for data concerning the level of economic activity and level of energy usage in the three major scenario pairs, the difference at the macroeconomic level between the scenarios without abatement effects and those with abatement effects appear quite similar.

Table 24.
Relative Stationary Source Treatment Efficiencies of Selected Pollutants for the Energy and Energy Abatement Scenarios
(Efficiencies in Percent of Residuals Removed)

	1975		1980		1985	
	Energy	Energy Abatement	Energy	Energy Abatement	Energy	Energy Abatement
Air Residuals						
Particulates	73.6	85.3	73.7	94.0	72.9	96.8
Sulfur Oxides	23.5	51.0	23.2	72.9	23.8	72.1
Nitrogen Oxides	0.2	2.5	0.2	5.6	0.3	5.7
Hydrocarbons	38.2	49.7	37.4	58.4	37.7	69.3
Carbon Monoxide	45.7	61.3	46.0	72.0	46.8	74.7
Water Residuals						
Biochemical Oxygen Demand	68.6	72.4	67.7	86.2	67.7	92.9
Suspended Solids	82.7	85.7	82.9	96.0	83.3	98.4
Dissolved Solids	30.9	33.6	32.1	43.7	34.1	61.4
Nutrients	35.2	37.1	38.6	47.0	40.0	53.1

Table 25.
Passenger Transportation Emission Levels for the Energy and Energy Abatement Scenarios
(Metric Tons per Million Vehicle Kilometers Travelled)

	1975		1980		1985	
	Energy	Energy Abatement	Energy	Energy Abatement	Energy	Energy Abatement
Air Residuals						
Particulates	0.22	0.19	0.22	0.17	0.23	0.16
Sulfur Oxides	0.09	0.09	0.10	0.10	0.11	0.11
Nitrogen Oxides	1.96	1.85	1.99	1.66	2.01	1.21
Hydrocarbons	2.63	2.26	2.19	1.24	2.10	0.54
Carbon Monoxide	21.83	17.74	21.97	10.35	22.06	3.64

Chapter 4
Sectoral Analyses Results

In order to assess the impacts of pollution abatement activities at a more detailed level than the macro-analysis presented in Chapter 3, a sectoral level analysis of one of the three abatement scenarios is required. In this chapter, the Reference Abatement Scenario is analyzed at the sectoral level to describe these micro-level impacts. Estimated reductions in pollutant residuals for industries, mobile sources, municipal treatment, and Federal, state, and local governments, which are derived from the Reference Abatement Scenario are analyzed first. Following this, the sectoral costs forecast for various industries to comply with Federal pollution control legislation are analyzed.

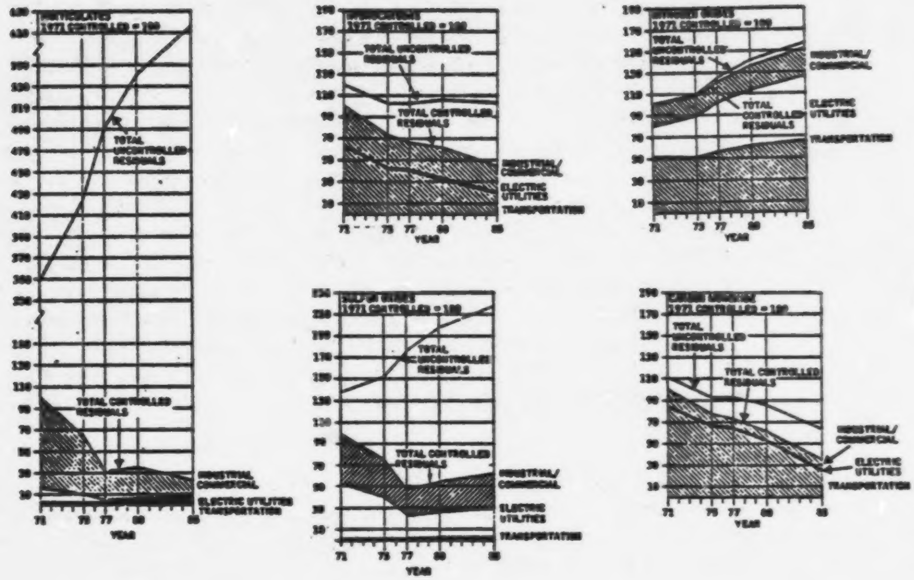
ESTIMATING THE REDUCTION IN AIR RESIDUAL GENERATION

The graphs In Figure 1 show the impacts of the Reference Abatement Scenario on generation of air residuals. In the graphs, the controlled (net) residual emission for each pollutant in 1971 is set equal to 100 and forecasts for subsequent years are indexed to the 1971 controlled emissions. Uncontrolled emissions are also shown indexed to the 1971 controlled emissions. The relative difference between the two plots indicates the overall effectiveness of pollution abatement technology for each pollutant in the forecast year. Controlled emissions are defined to be those that enter the receiving media (air, water) from the generating source after the abatement process is completed. The relative contribution to total controlled emissions in air by industrial/commercial sources, electric utilities and municipal treatment is shown by the distance between the appropriately labeled curves on each graph.

Reduction in residuals discharged to the nation's environment, as shown in Figure 1, is only a rough indicator of environmental quality. However, significant increases or decreases of the various types of emissions are indicative of probable changes in ambient trends. Therefore, the graphs afford a measure of the probable environmental quality so far as air is concerned.

The major source of each air pollutant is illustrated in Figure 1. Particulates and sulfur oxide emissions in 1971 result primarily from activity in the stationary sources (industrial/commercial and electric utilities) while the major cause of hydrocarbons and carbon monoxide is mobile sources (transportation). Nitrogen oxide emissions are approximately equal from fixed and mobile sources in 1971 and are shown to be difficult to abate in both sources.

Figure 1.
Trends in Air Residuals from the Reference Abatement Scenario



For the major stationary-source residuals (particulates and sulfur dioxide), decreasing emissions are shown until 1977. The end of 1977 was chosen in the Reference Case scenarios to be the date that full compliance to the Clean Air Act for all fixed sources occurs. After 1977, the plots of both sulfur oxide and particulate emissions from fixed sources level until 1980 and sulfur oxides even shows slight increases to 1985. This represents a pattern approximating the growth in economic activity without significant subsequent increases in pollution abatement efficiencies for these two pollutants. This pattern is found for particulates from 1977-1980 and for sulfur oxides from 1977-1985. (There is a slight dampening in the growth of the emissions from these sources compared with the economic growth over the 1977-1980 or 1977-1985 period due to more stringent controls on emissions from new plants.) The index of emissions for particulates relative to the 1971 total show the mobile sources share to be approximately constant at 3 percent from 1971 through 1985; the index for industrial/commercial sectors decreases from 84 percent in 1971 to 16 percent in 1985; and the electric utilities index declines sharply from 13 percent to 2 percent by 1977 and then becomes fairly constant. The relative indices for sulfur oxides emissions show the mobile source share increasing from 2 percent in 1971 to 3 percent in 1985. The index for the industrial/commercial source remains fairly constant throughout the interval, decreasing slightly by 1977, while the electric utilities index decreases from approximately 50 percent in 1971 to about 25 percent in 1985.

Turning to air pollutants where mobile sources are most important, the graph for hydrocarbon and carbon monoxide emissions both show a steady decrease to 1985. Emissions standards for both pollutants for automobiles are scheduled for full compliance in 1978. The steady decrease in the graphs after that time is due to phaseout of the older model-year automobiles from vehicles still on the road that occurs in each successive year since older automobiles are not as well controlled as new models. This factor tends to offset any increases in stationary source emissions after 1977, which result from growth in economic output. Uncontrolled hydrocarbon and carbon monoxide emissions show a decrease from 1971 to 1975, because older automobiles (pre-1968 model years) have hydrocarbon and carbon monoxide emission factors approximately 120 percent larger than those for the 1971 model year. Many of these automobiles were still in use in 1971 and are phased out throughout the forecast period. This effect continues after 1977 for carbon monoxide due to the existence of more strict control standards after that time. The mobile sources index of hydrocarbons decreases from 63 percent in 1971 to 20 percent in 1985 while the index for hydrocarbon emissions from stationary sources decreases from 37 percent to 25 percent. Corresponding values for carbon monoxide are 85 to 25 percent and 15 to 9 percent.

Nitrogen oxide uncontrolled emissions increase 57 percent over the course of the forecast period. The electric utilities index to 1971 controlled emissions increases from 29 to 61 percent, while the mobile source index increases from 52 percent to 65 percent; the remainder from industrial/commercial sources is fairly constant. The forecast increase in nitrogen oxide controlled emissions due to mobile sources is probably underestimated by this forecast because it is assumed that the presently legislated 1978 standard will be met. If the 1978 standard is modified or not met, which appears to be quite possible, the increase in nitrogen oxide emissions would be even more severe.

Table 1 shows further detail concerning the largest contributors to the industrial/commercial share of emissions for air residuals after controls. The combustion of fossil fuels by 1985 causes the largest proportion of both sulfur oxide and nitrogen oxide emissions. For particulates, the greatest source by far of emissions is the Crushed Stone subsector, particularly in 1980. The consumption of gasoline at service stations and the production and use of solvent-based paints dominate the generation of hydrocarbon emissions in 1971 and increase their shares by 1985. In 1985, the production and consumption of Solvent-Based Paints yield over 40 percent of the industrial/commercial share of hydrocarbons and about 25 percent of the total hydrocarbon emissions from all sources. Several sectors/subsectors, such as Asphalt Production in particulates and Crude Oil Refining in sulfur oxides, have large shares of controlled emissions in 1971; however, because of improved treatment efficiencies, they make small contributions to the aggregate industrial/commercial residuals in 1985.

Differences in air residuals as forecast in the Low Productivity Abatement and Energy Abatement Scenarios are presented in Table 2 as percent changes from the forecast for major polluting industries in the Reference Abatement Scenario. For the Low Productivity Abatement Scenario, one might expect these differences to be on the order of the percent change in GNP, as shown at the bottom of the table. The general tendency, however, is for residual production to change at lower rates than GNP, with the notable exception of the industrial and commercial use of fossil fuels. As expected, little difference is seen between the Energy

Abatement and the Reference Abatement Scenarios other than in the energy related sectors, where significantly lower residuals are forecast for the Energy Abatement Scenario.

Table 1.
Industrial/Commercial Net Air Residuals by Major Contributing Sectors/Subsectors

	Percent of Industrial and Elec. Emissions from Reference Abatement Scenario			
Sectors/Subsectors	1971	1975	1980	1985
Particulates				
Stone & Clay Products Crushed Stone	21.4	34.2	70.7	46.7
Electric Utilities Elec. by Coal	12.9	12.7	4.3	7.9
Paving & Asphalt Asphalt	11.2	8.5	1.4	1.0
Cement, Concrete, Gypsum				
Cement-Dry Grinding	8.6	7.2	1.4	0.3
Cement-Wet Grinding	8.0	6.1	1.0	0.2
Steel	6.5	5.4	2.7	3.9
Cement, Concrete, Gypsum Lime	3.6	2.9	0.3	0.6
Industrial Combustion of Coal	3.2	2.4	0.4	0.8
Sulfur Oxides				
Electric Utilities Elec. by High Sulfur Coal	46.9	42.6	26.5	24.1
Petroleum Refining Crude Oil Refining	7.6	4.6	0.6	0.7
Commercial/Institutional Use of Residual Oil	3.8	5.4	7.8	11.8
Petroleum Refining-Ind. Combustion of Oil	3.6	6.3	11.1	12.0

Table 1. (Continued)
Industrial/Commercial Net Air Residuals by Major Contributing Sectors/Subsectors

Sectors/Subsectors	Percent of Industrial and Elec. Emissions from Reference Abatement Scenario			
	1971	1975	1980	1985
Crude Petro. Nat. Gas				
Sour Nat. Gas Proc. Plants	3.3	1.9	0.1	0.1
Electric Utilities				
Elec. by High Sulfur Residual Oil	3.3	2.9	2.2	2.5
Elec. by Low Sulfur Coal	0.8	4.4	12.0	14.4
Nitrogen Oxides				
Electric Utilities				
Elec. by Coal	41.6	48.1	50.7	50.3
Elec. by Gas	10.8	8.1	5.5	5.5
Elec. by Oil	8.9	11.4	13.5	14.7
Petroleum Refining				
Industrial Combustion of Oil	3.8	3.2	2.5	2.5
Hydrocarbons				
Service Stations				
Gasoline Consumption	17.3	25.5	29.3	24.9
Paints				
Solvent Base Paints Production	17.0	22.2	26.3	32.9
Open Burning	10.2	0	0	0
Solvent Based Paints Consumption	10.1	10.6	9.8	11.1
Petroleum Refining				
Crude Oil Refining	8.5	5.6	2.2	3.1
Gasoline Production	6.8	7.0	5.7	8.5

Table 1. (Continued)
Industrial/Commercial Net Air Residuals by Major Contributing Sectors/Subsectors

Sectors/Subsectors	Percent of Industrial and Elec. Emissions from Reference Abatement Scenario			
	1971	1975	1980	1985
Industrial Chemicals				
Ethylene Oxide	3.2	2.0	0.4	0.5

Table 2.
Percent Changes in Air Residuals from the Major Polluting Industries for Alternative Abatement Scenarios Compared with the Reference Abatement Scenario

	Percent Difference from the Reference Abatement Scenario (S2)							
	Low Productivity Abatement (S4)				Energy Abatement (S6)			
Sectors/Subsectors	1971	1975	1980	1985	1971	1975	1980	1985
Particulates								
Stone & Clay Products								
Crushed Stone	0.0	3.1	-8.2	-9.1	0.0	-0.2	-0.4	-0.3
Electric Utilities								
Electricity by Coal	0.0	2.0	-5.1	-9.1	0.0	-1.7	-5.5	-13.7
Paving & Asphalt								
Asphalt	0.0	2.8	-7.1	-8.6	0.0	-0.1	-0.3	-0.2
Cement, Concrete, Gypsum								
Cement-Dry Grinding	0.0	3.4	-8.9	-9.6	0.0	-0.2	-0.5	-0.3
Cement-Wet Grinding	0.0	3.4	-8.9	-9.6	0.0	-0.2	-0.5	-0.3
Steel	0.0	2.0	-10.1	-10.2	0.0	-0.2	-0.7	-2.0
Cement, Concrete, Gypsum								
Lime	0.0	3.2	-9.0	-10.2	0.0	-0.2	-0.4	-1.3
Industrial Combustion of Coal								
N.E.C.	0.0	4.4	-8.8	-12.3	0.0	0.0	0.0	0.2
Sulfur Oxides								
Electric Utilities								
Electricity by High Sulfur Coal	0.0	2.0	-5.1	-9.1	0.0	-1.7	-5.5	-13.7

Table 2. (Continued)
Percent Changes in Air Residuals from the Major Polluting Industries for Alternative Abatement Scenarios Compared with the Reference Abatement Scenario

	Percent Difference from the Reference Abatement Scenario (S2)							
	Low Productivity Abatement (S4)				Energy Abatement (S6)			
Sectors/Subsectors	1971	1975	1980	1985	1971	1975	1980	1985
Petroleum Refining Crude Oil Refining	0.0	2.1	-4.9	-6.5	0.0	-7.4	-7.4	-14.2
Commercial/Institutional Use of Residual Oil	0.0	4.6	-8.1	-13.4	0.0	0.2	0.0	0.7
Petroleum Refining Industrial Combustion of Oil	0.0	2.1	-5.0	-6.5	0.0	-7.4	-7.4	-14.2
Crude Petroleum, Natural Gas Sour Natural Gas Proc. Plants	0.0	1.6	-3.5	-5.6	0.0	-0.5	-3.4	-4.0
Electric Utilities Electricity by High Sulfur Residual Oil	0.0	2.0	-5.1	-9.1	0.0	-1.7	-5.5	-13.7
Electricity by Low Sulfur Coal	0.0	2.0	-5.1	-9.1	0.0	-1.7	-5.5	-13.7
Nitrogen Oxides								
Electric Utilities Electricity by Coal	0.0	2.0	-5.1	-9.1	0.0	-1.7	-5.5	-13.7
Electricity by Gas	0.0	2.0	-4.9	-8.7	0.0	-1.6	-5.4	-13.1
Electricity by Oil	0.0	2.0	-5.1	-9.1	0.0	-1.7	-5.5	-13.7
Petroleum Refining Industrial Combustion of Oil	0.0	2.1	-4.9	-6.5	0.0	-7.4	-7.4	-14.2
Hydrocarbons								
Service Stations Gasoline Consumption	0.0	0.7	-2.1	-2.9	0.0	-12.4	-24.4	-35.8
Paints Solvent Base Paint Production	0.0	3.9	-8.1	-11.7	0.0	0.0	0.0	0.4

Table 2. (Continued)
Percent Changes in Air Residuals from the
Major Polluting Industries for Alternative
Abatement Scenarios Compared with
the Reference Abatement Scenario

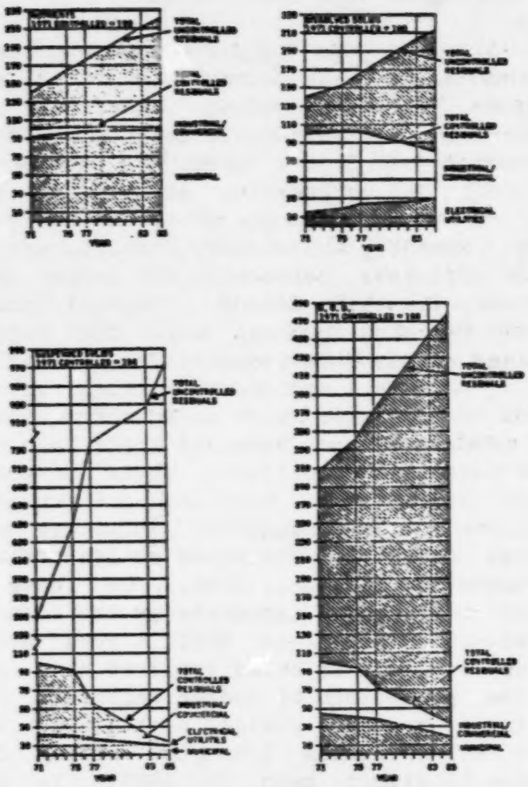
	Percent Difference from the Reference Abatement Scenario (S2)							
	Low Productivity Abatement (S4)				Energy Abatement (S6)			
Sectors/Subsectors	1971	1975	1980	1985	1971	1975	1980	1985
Open Burning	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solvent Based Paints Consumption	0.0	2.8	-5.3	-8.3	0.0	0.1	0.1	0.4
Petroleum Refining								
Crude Oil Refining	0.0	2.1	-4.9	-6.5	0.0	-7.4	-7.4	-14.2
Gasoline Production	0.0	0.7	-2.1	-2.9	0.0	-12.4	-24.4	-35.8
Industrial Chemicals								
Ethylene Oxide	0.0	6.4	-10.6	-13.5	0.0	0.0	0.1	-0.6

ESTIMATING THE REDUCTION IN WATER RESIDUAL GENERATION

Figure 2 presents graphs for water residuals which are similar to those in Figure 1. The shape of the total water residual curves (see Figure 2) does not show any increases after 1977 similar to the total controlled air residual curves for sulfur oxides. (However, the controlled level of nutrients remains approximately the same after 1977 since the increase in tertiary treatment of municipal sewage is only sufficient to offset the increase in uncontrolled nutrients due to population growth.) This is due primarily to the phased abatement schedule for water effluents in the 1972 amendments. The Reference Abatement Scenario assumes that BPT is operational by 1977 and BAT is operating by 1983; therefore, there is a continual increase in most water effluent removal efficiencies until 1983. Other than the change from the sulfur oxides curve, the curves for the total uncontrolled water residuals show shapes similar to the remaining air residual curves, responding to increases in economic output and population.

Industrial/commercial and municipal sewage contribute approximately equal, but declining, shares to BOD effluents through 1985. All three sources, industrial/commercial, municipal sewage, and electric utilities, contribute to suspended solids emissions. In 1971, the industrial/commercial index was approximately 78 percent of all suspended solids emissions; however, this index diminishes to less than 6 percent by 1985 while the municipal sewage index changes only from 21 percent in 1971 to about 10 percent in 1985.

Figure 2.
Trends in Water Residuals from the
Reference Abatement Scenario



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The composition of dissolved solids emissions is almost totally (85 percent) from industrial/commercial sources in 1971; by 1985 the industrial/commercial index has dropped to 50 percent while the electric utilities index has grown from 15 percent to 30 percent, primarily due to electric generation by coal. Nutrients (composed of phosphate and nitrate effluents) are almost totally due to municipal sources for all years and remain at a relatively constant level throughout the time period.

Table 3 shows the largest economic sector and subsector contributors to the industrial/commercial share of effluents for water. Municipal sewage treatment is excluded from consideration in this table because residuals attributed to this sector come from a variety of sources in addition to industrial and commercial establishments. For BOD, Pulp Mills are the major source of effluents in 1971. However, by 1985, Forestry and Fishery Products has the largest share of BOD effluents, reflecting the lesser degree of treatment efficiency for this sector. Asphalt production and the Bauxite Refining process were the largest polluters of suspended solids from industrial/commercial sources in 1971. By 1985, however, sectors/subsectors with less efficient control technologies, such as Forestry and Fishery Products, Lime production, and Bleached Kraft Pulp Mills, account for almost half of the effluent while suspended solids from Asphalt and Bauxite Refining are completely controlled. Subsectors of the Industrial Chemicals sector yield the greatest share of dissolved solids effluents prior to the implementation of BAT in 1983. Of these subsectors, the production of sodium carbonate by the Solvay process was the largest contributor in 1971. This economic production process, however, is being replaced by a competing process for the production of sodium carbonate, the Trona process. The Trona process yields negligible water residuals; therefore, effluents from the Sodium Carbonate process decrease to almost zero in 1985. In contrast to this pattern, the share for Citric Acid production increases from less than 25 percent to over 50 percent of industrial/commercial suspended solids effluents over the period because the production of Citric Acid increases to double the 1971 value by 1985.

Table 4 presents the percent differences in water residuals forecast for the major polluters of the Reference Abatement Scenario in the Low Productivity Abatement and Energy Abatement Scenarios as compared with water residuals from those polluters found in the Reference Abatement Scenario. The same general trends between scenarios are evidenced for water residual differences as for air residuals. The trends for the Energy Abatement Scenario are, however, less pronounced because major changes in assumptions made for this scenario impacted primarily on air residuals rather than on water residuals.

Table 3.
Industrial/Commercial Net Water Residuals by Major Contributing Sectors/Subsectors

Sectors/Subsectors	Percent of Industrial and Elec. Emissions from Reference Abatement Scenario 1971	1977	1983	1985
Biochemical Oxygen Demand				
Pulp Mills Kraft-Bleached	13.1	11.1	7.5	6.7
Plastic Materials & Resins	8.6	13.3	11.4	8.0
Forestry & Fishery Products	7.4	14.6	33.4	40.6
Pulp Mills Sulfite-Pulp	6.0	5.5	3.5	2.5
Pulp Mills Kraft-Unbleached	5.9	5.6	5.8	5.9
Suspended Solids				
Paving & Asphalt Asphalt	26.3	19.1	0	0
Aluminum Bauxite Refining	25.3	18.9	0	0
Steel	13.5	12.4	7.5	3.7
Cement, Concrete, Gypsum Lime	7.7	1.7	9.2	16.6
Pulp Mills Kraft-Bleached	4.7	7.0	13.0	13.5
Forestry & Fishery Products	4.2	9.7	19.7	17.1

Table 3. (Continued)
Industrial/Commercial Net Water Residuals by Major Contributing Sectors/Subsectors

Sectors/Subsectors	Percent of Industrial and Elec. Emissions from Reference Abatement Scenario			
	1971	1977	1983	1985
Dissolved Solids				
Industrial Chemicals				
Sodium Carbonate-Solvay Process	39.0	29.8	7.6	0
Citric Acid	23.0	27.2	45.2	50.6
Electric Utilities				
Electricity by Coal	14.1	24.2	31.8	34.9
Industrial Chemicals				
Chlorine-Diaphragm Cell	2.3	3.5	1.5	0

Table 4
Percent Changes in Water Residuals from the Major Polluting Industries for Alternative Abatement Scenarios Compared with the Reference Abatement Scenario

	Percent Difference from the Reference Abatement Scenario (S2)							
	Low Productivity Abatement (S4)				Energy Abatement (S6)			
Sectors/Subsectors	1971	1977	1983	1985	1971	1977	1983	1985
Biochemical Oxygen Demand								
Pulp Mills Kraft-Bleached	0.0	1.1	-9.0	-10.3	0.0	0.6	-0.9	-1.6
Plastic Materials & Resins	0.0	1.3	-10.7	-12.1	0.0	-0.2	-2.1	-2.8
Forestry & Fishery Products	0.0	1.4	-15.5	-17.5	0.0	0.2	-0.3	0.2
Pulp Mills Sulfite-Pulp	0.0	1.3	-8.5	-9.8	0.0	0.3	0.3	0.5
Pulp Mills Kraft-Unbleached	0.0	1.1	-9.0	-10.3	0.0	0.6	-0.9	-1.6
Suspended Solids								
Paving & Asphalt Asphalt	0.0	0.9	0	0	0.0	0.0	0	0
Aluminum Bauxite Refining	0.0	1.1	0	0	0.0	0.0	0	0

Table 4. (Continued)
Percent Changes in Water Residuals from the Major Polluting Industries for Alternative Abatement Scenarios Compared with the Reference Abatement Scenario

	Percent Difference from the Reference Abatement Scenario (S2)							
	Low Productivity Abatement (S4)				Energy Abatement (S6)			
Sectors/Subsectors	1971	1977	1983	1985	1971	1977	1983	1985
Steel	0.0	0.5	-10.1	-10.6	0.0	0.1	-0.9	-1.2
Cement, Concrete, Gypsum Lime	0.0	1.1	-9.2	-10.2	0.0	0.0	-1.1	-1.3
Pulp Mills Kraft-Unbleached	0.0	1.1	-9.0	-10.3	0.0	0.6	-0.9	-1.6
Forestry & Fishery Products Dissolved Solids	0.0	1.4	-15.5	-17.5	0.0	0.2	-0.3	0.2
Industrial Chemicals								
Sodium Carbonate-Solvay Process	0.0	1.2	-10.3	0	0.0	-0.1	-1.3	0
Citric Acid	0.0	2.4	-11.0	-13.9	0.0	0.3	0.8	1.3
Electric Utilities Electricity by Coal	0.0	0.9	-7.5	-9.1	0.0	-3.5	-9.5	-13.7
Industrial Chemicals Chlorine-Diaphragm Cell	0.0	1.4	-10.3	-11.6	0.0	0.0	-1.0	-1.3

ESTIMATING THE COST OF POLLUTION CONTROL

Assuming air and water pollution controls, associated cost functions, and the Reference Case growth in GNP, direct costs of pollution control for each industry sector can be forecast using SEAS. Using these forecasts, the total annual costs (annualized capital plus O&M) for the 1976-85 period for all industries will be:

Industrial Control Costs (Billions 1975$)	$231.8
Air Costs	$111.1
Water Costs	$120.7

The detailed distribution of these costs across aggregate industrial sectors is shown in Table 5. Note that Electric Power Plants must expend about a fourth of the air pollution costs. Nearly another quarter of the air costs are borne by many different industries in order to provide space heating, with Chemicals and Paper being the major aggregate industries making this expenditure.

By far the largest water pollution control expenditure is made by the Machinery and Equipment sector (this includes the aggregate sectors of electroplating, fabricated metal products, and electrical and nonelectrical machinery). This sector is required to expend over 50 percent of all industrial water pollution control expenditures. The Chemicals sector is the second largest spender for water pollution control (in particular, Organic Chemicals, Inorganic Chemicals, and Plastics and Synthetics), and will be required to spend slightly over 16 percent of the total industrial control costs for water pollutants.

When air and water pollution control costs are combined, the preponderance of Machinery and Equipment expenditures for water pollution control also make it the aggregate sector, expending over twice the amount that any other aggregate sector expends for total pollution control even though no air pollution control expenditures are required. The share of total pollution control equipment costs for Machinery and Equipment is 29 percent. Of the remaining aggregate sectors, five show total pollution control costs in excess of 5 percent of the national industrial pollution control costs: Electric Utilities (14 percent); Other (11 percent); Pulp, Paper, Printing, and Lumber (8 percent); Ferrous Metals (8 percent); and Chemicals (7 percent). Together, these six aggregate sectors account for two-thirds of national industrial pollution control costs.

Table 5.
Annualized National Control Costs for Air and Water Pollution Abatement (excluding Transportation and Municipal Control Costs), 1976-1985
(In Millions of 1975 Dollars)

	------AIR------		-----WATER-----		---AIR & WATER---	
Aggregated Industrial Sectors	Total Costs	% of National Costs	Total Costs	% of National Costs	% of Total Costs	National Costs
Agriculture	0	0	291	0.2	291	0.1
Mining	588	0.5	0	0	599	0.3
Food Processing	3,629	3.3	6,203	5.1	9,832	4.2
Textiles	316	0.3	642	0.5	958	0.4
Pulp, Paper, Printing & Lumber	11,864	10.7	7,887	6.5	19,751	8.5
Chemicals	6,407	5.8	19,732	16.4	16,139	6.9
Petroleum & Rubber	6,280	5.7	2,692	2.2	8,972	3.9
Ferrous Metals	11,885	10.7	7,486	6.2	19,371	8.3
Nonferrous Metals	9,784	8.8	1,506	1.3	10,290	4.4
Stone, Clay, & Glass	6,317	5.7	502	0.4	6,819	3.0
Machinery & Equipment	1,619	1.5	65,795	54.5	67,414	29.0
Electric Utilities	24,538	22..1	7,455	6.2	31,993	13.7
Trade & Services	3,622	3.3	0	0	3,622	1.6
Other	24,237	21.8	525	0.4	24,762	10.6
National Totals	111,086		120,716		232,802	

To illustrate the components of the cost estimates for each industry, two aggregate industrial sectors (Paper and Printing, and Ferrous Metals) may be examined in greater detail. Table 6 shows the cost sectors involved in each of these aggregate sectors and their associated air pollution abatement expenditures. Note that Kraft Pulping contributes more than 85 percent of the air pollution control expenditures for the aggregate Paper and Printing sector. Similarly, the manufacture of iron and steel mill products comprise the bulk of the Ferrous Metals expenditures for air pollution control.

Table 6.
Air Pollution Abatement Expenditure Detail for Paper and Ferrous Metals

	% of Total Annual Air Expenditures (1976-85)	
Pulp, Paper, Printing & Lumber	10.7	
Kraft Pulp		9.3
NSSC Pulp		1.2
Printing		0.2
Lumber		0.0
Ferrous Metals	10.7	
Iron and Steel		7.2
Iron Foundries		2.3
Steel Foundries		0.6
Ferroalloys		0.7

Kraft Pulping expenditures for air pollution control are calculated using 11 industrial process segments while the expenditures for Iron and Steel manufacture are calculated using 22 industrial process segments. The 11 segments for Kraft Pulping and their contribution to the Kraft Pulping total are shown in Table 7.

Table 7.
Air Pollution Cost Detail by Segment for Kraft Pulping

	% of Total Annual Air Expenditures	
Paper		
Kraft Pulping	9.3	
Lime Kiln		0.10
Smelting Tank		0.08
Gas Incineration in Recovery Furnace		0.10
Gas Incineration in Lime Kiln		0.10
Boiler--Suspended Particulates		0.28
Boiler--Sulfur Oxides		3.53
Recovery Furnace		
Scrubber		0.03
Black Liquor Oxidation		0.28
Replacement		1.03
Electrostatic Precipitator		0.57
Industrial Fuel Combustion		3.20

Industry Investment

The difficulties that a given industry faces in making pollution control expenditures are dependent upon many factors. Two of these factors are the size of the pollution control expenditures as a percentage of total output by the industry and the pollution control investment required as a percentage of the total expected investment by that industry. Data for 31 aggregate industries concerning each of these factors are shown in Tables 8 and 9. Table 10 summarizes this data for air, water, and total pollution control expenditures and investments for the 31 aggregate industries and also ranks the industries based on each percentage.

Table 8.
Relative Impacts of Required In-House Pollution Abatement Expenditures, 1976-1985
(Million 1975$)

		Air		Water		Air & Water	
Category	Output	Total Cost	% of Output	Total Cost	% of Output	Total Cost	% of Output
Agriculture	1,260,713	0	0	291	0.02	291	0.02
Mining	225,684	165	0.07	0	0	165	0.07
Natural Gas Processing	243,857	423	0.17	0	0	423	0.17
Meat & Poultry	491,305	0	0	1,059	0.22	1,059	0.22
Dairy	189,350	0	0	1,338	0.71	1,338	0.71
Canned & Frozen Food	226,182	0	0	3,638	1.61	3,638	1.61
Grain Milling & Feed Mills	195,772	3,629	1.85	47	0.02	3,675	1.88
Beet & Cane Sugar	50,796	0	0	121	0.24	121	0.24
Textiles	650,571	316	0.05	641	0.10	957	0.15
Lumber & Wood Products	178,630	0	0	425	0.24	425	0.24
Furniture	213,699	1,849	0.86	0	0	1,849	0.86
Pulp & Paper	367,951	9,904	2.69	7,276	1.98	17,181	4.67
Builder's Paper	138,245	0	0	184	0.13	184	0.13
Printing	445,666	111	0.02	0	0	111	0.02
Chemicals	505,520	5,275	1.04	16,386	3.24	21,661	4.29
Fertilizers	52,841	512	0.97	372	0.70	884	1.67
Plastics & Synthetics	223,432	501	0.22	2,974	1.33	3,476	1.56
Petroleum & Asphalt	629,999	6,280	1.00	2,446	0.39	8,725	1.38
Paints	58,891	119	0.26	0	0	119	0.26
Rubber Products	184,603	0	0	246	0.13	246	0.13
Leather Tanning	14,719	0	0	525	3.57	525	3.57
Glass	110,432	0	0	212	0.19	212	0.19
Asbestos, Clay, Lime, & Concrete	274,559	5,974	2.17	290	0.11	6,264	2.28
Iron & Steel	540,843	11,885	2.20	7,481	1.38	19,366	3.58
Nonferrous Metals	405,332	9,784	2.42	1,506	0.37	11,290	2.79
Fabricated Metals & Electroplating	999,503	0	0	32,451	3.26	32,451	3.26

Table 8. (continued)
Relative Impacts of Required In-House
Pollution Abatement Expenditures, 1976-1985
(Million 1975$)

		Air		Water		Air & Water	
Category	Output	Total Cost	% of Output	Total Cost	% of Output	Total Cost	% of Output
Machinery	1,258,102	1,148	0.09	21,710	1.73	22,858	1.82
Transportation Equipment	1,763,120	471	0.03	11,634	0.67	12,105	0.70
Electric Utilities	792,675	24,538	3.10	7,455	0.94	31,992	4.04
Wholesale & Retail	4,721,246	3,317	0.07	0	0	3,317	0.07
Services	5,728,522	305	0.01	0	0	305	0.01
Other Industries	N.A	24,237	N.A	0	N.A	24,237	N.A
Totals	N.A	110,743	N.A	120,708	N.A	231,450	N.A

Table 9.
Relative Impacts of Required In-House Pollution
Abatement Investment, 1976-1985
(Million 1975 $)

Category	Total Investment	Air Abatement Investment	%	Water Abatement Investment	%	Total Air & Water Investment	% Total Investment
Agriculture	75,569	0	0	112	0.15	112	0.15
Mining	33,392	134	0.40	0	0	134	0.40
Natural Gas Processing	21,736	51	0.24	0	0	51	0.24
Meat & Poultry	6,998	0	0	492	7.04	492	7.04
Dairy	5,558	0	0	516	9.28	516	9.28
Canned & Frozen Food	11,236	0	0	1,740	15.48	1,740	15.48
Grain Milling & Feed Mills	6,642	1,021	15.37	13	0.19	1,033	15.56
Beet & Cane Sugar	4,017	0	0	31	2.91	31	2.91
Textiles	29,289	88	0.30	378	1.29	467	1.59
Lumber & Wood Products	17,624	0	0	71	0.40	71	0.40
Furniture	6,634	90	1.36	0	0	90	1.36
Pulp & Paper	49,672	2,030	4.09	5,024	10.12	7,055	14.20
Builder's Paper	7,337	0	0	123	1.68	123	1.68
Printing	25,072	22	0.09	0	0	22	0.09
Chemicals	66,566	1,096	1.65	5,404	8.12	6,501	9.77
Fertilizers	5,373	98	1.82	243	4.52	340	6.34
Plastics & Synthetics	20,696	140	0.68	1,560	7.54	1,699	8.21
Petroleum & Asphalt	34,207	1,121	3.28	1,670	4.88	2,791	8.16
Paints	2,235	12	0.53	0	0	12	0.53
Rubber Products	16,210	0	0	130	0.80	130	0.80
Leather Tanning	409	0	0	280	68.43	280	68.43
Glass	8,484	0	0	102	1.21	102	1.21
Asbestos, Clay, Lime, & Concrete	18,513	628	3.39	91	0.49	719	3.38
Iron & Steel	56,016	2,019	3.60	2,321	4.14	4,340	7.75
Nonferrous Metals	28,061	1,157	4.12	224	0.80	1,381	4.92

Table 9. (continued)
Relative Impacts of Required In-House Pollution Abatement Investment, 1976-1985
(Million 1975 $)

Category	Total Investment	Air Abatement Investment	%	Water Abatement Investment	%	Total Air & Water Investment	% Total Investment
Fabricated Metals & Electroplating	54,550	0	0	8,298	15.21	8,298	15.21
Machinery	61,358	118	0.19	7,317	11.93	7,436	12.12
Transportation Equipment	101,169	131	0.13	3,451	3.41	3,583	3.54
Electric Utilities	127,174	7,906	6.22	5,376	4.23	3,282	10.44
Wholesale & Retail	229,612	1,207	0.53	0	0	1,207	0.53
Services	201,538	80	0.04	0	0	80	0.04
Other Industries	N.A	4,411	N.A	0	N.A	4,411	N.A
Totals	N.A	23,560	N.A	44,967	N.A	68,529	N.A

Table 10.
Ranking of Impacted Sectors by Total Abatement Expenditures as Percentages of Total Output and by Abatement Investment as Percentages of Other Planned Investment (1976-1985)[1]

	Investment						Output					
	Air Rank	%	Water Rank	%	Both Rank	%	Air Rank	%	Water Rank	%	Both Rank	%
Pulp & Paper	4	4.09	5	10.12	5	14.20	2	2.69	4	1.98	1	4.67
Chemicals	9	1.65	7	8.12	8	9.77	7	1.04	3	3.24	2	4.29
Electric Utilities	2	6.22	12	4.23	7	10.44	1	3.10	9	0.94	3	4.04
Iron & Steel	5	3.60	13	4.14	12	7.75	4	2.24	7	1.38	4	3.62
Leather Tanning	-	-	1	68.43	1	68.43	-	-	1	3.58	5	3.58
Fabricated Metals and Electroplating	-	-	3	15.21	4	15.21	-	-	2	3.25	6	3.25
Nonferrous Metals	3	4.12	19	0.80	16	4.92	3	2.42	14	0.37	7	2.79
Asbestos, Clay, Lime, and Concrete	6	3.39	21	0.49	15	5.86	5	2.17	21	0.11	8	2.28
Grain Milling & Feed Mills	1	15.37	23	0.19	2	15.56	6	1.85	23	0.02	9	1.88
Machinery	17	0.19	4	11.93	6	12.12	14	0.09	5	1.73	10	1.82
Fertilizers	8	1.82	11	4.52	14	6.34	9	0.97	11	0.70	11	1.67
Canned & Frozen Food	-	-	2	15.48	3	15.48	-	-	6	1.61	12	1.61
Plastics & Synthetics	11	0.68	8	7.54	10	8.21	12	0.22	8	1.33	13	1.56
Petroleum & Asphalt	7	3.28	10	4.88	11	8.16	8	1.00	13	0.39	14	1.38
Furniture	10	1.36	-	-	21	1.36	10	0.86	-	-	15	0.86
Dairy	-	-	6	9.28	9	9.28	-	-	10	0.70	16	0.70
Transportation Equipment	18	0.13	14	3.41	17	3.54	18	0.03	12	0.66	17	0.69
Paints	12	0.53	-	-	24	0.53	11	0.26	-	-	18	0.26
Beet & Cane Sugar	-	-	15	2.91	18	2.91	-	-	15	0.24	19	0.24
Lumber & Wood Products	-	-	22	0.40	26	0.40	-	-	16	0.24	20	0.24
Meat & Poultry	-	-	9	7.04	13	7.04	-	-	17	0.22	21	0.22
Glass	-	-	18	1.21	22	1.21	-	-	18	0.19	22	0.19
Natural Gas Processing	16	0.24	-	-	28	0.24	13	0.17	-	-	23	0.17
Textiles	15	0.30	17	1.29	20	1.59	17	0.05	22	0.10	24	0.15
Builder's Paper	-	-	16	1.68	19	1.68	-	-	19	0.13	25	0.13
Rubber Products	-	-	20	0.80	23	0.80	-	-	20	0.13	26	0.13

Table 10. (continued)
Ranking of Impacted Sectors by Total Abatement Expenditures as Percentages of Total Output and by Abatement Investment as Percentages of Other Planned Investment (1976-1985)[1]

	Investment						Output			
	Air		Water		Both		Air		Water	Both
	Rank	%	Rank	%	Rank	%	Rank	%ank	%ank	%
Wholesale & Retail	13	0.53	-	-	25	0.53	150.07	-	-27	0.07
Mining	14	0.40	-	-	27	0.40	160.07	-	-28	0.07
Printing	19	0.09	-	-	30	0.09	190.03	-	-29	0.03
Agriculture	-	-	24	0.15	29	0.15	-	-240.0230		0.02
Services	20	0.04	-	-	31	0.04	200.01	-	-31	0.01

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[1] This table, while analogous to Table 4 of the Executive Summary, does not include the adjustments to industries where specific studies were undertaken at a later date.

Of the 31 industrial sectors shown in Table 10, thirteen require abatement expenditures for both air and water. Industries with high air pollution control costs often have significant water pollution control costs as well. However, industries with high water pollution expenditure control costs are less likely to also have air control expenditures.

Water pollution control investments dominate the air pollution equipment investments, similar to the total expenditure pollution control cost patterns discussed above. Of the 10 largest investors, four have water pollution control investments only, including three of the top four. In the remaining six industries, three others show pollution control investments heavily weighted towards water, two show about even splits between air and water, and one is heavily weighted towards air. Finally, of the top 10 industries for air pollution control investments, nine also must make water pollution control investments; however, only five of the top 10 industries for water pollution investment must also make air pollution control investments.

Considering air expenditures, the Grain Milling and Feed Mills industry will have to make a 15.4 percent addition to total expected investment during the 1976-85 period if it is to adequately control air pollution. Other industries with large air pollution investment requirements of greater than 3 percent of other investment requirements are: Electric Utilities (6.2 percent), Nonferrous Metals (4.1 percent), Pulp and Paper 4.1 percent), Iron and Steel 3.6 percent), Asbestos, Clay, Lime, and Concrete (3.4 percent), and Petroleum and Asphalt (3.3 percent).

The total annual air pollution control costs during the 1976-85 period as percentages of the total output value for each sector are much smaller than the above ratios. The highest sectors for these annual cost ratios are: Electric Utilities (3.1 percent); Pulp and Paper (2.7 percent); Nonferrous Metals (2.4 percent); Asbestos, Clay, Lime, and Concrete (2.3 percent); Iron and Steel (2.2 percent); and Grain Milling and Feed Mills (1.9 percent). Because some sectors are more or less capital-intensive than others in their air pollution abatement costs, this list is significantly different from the previous list.

Similar percentages concerning water pollution abatement investment to those presented for air pollution control may be calculated. The comparison of water pollution control investment to other planned investment yields the following ranking for most heavily impacted industries:

Leather Tanning	68.43%
Canned & Frozen Food	15.48%
Fabricated Metals & Electroplating	15.21%
Machinery	11.93%
Pulp & Paper	10.12%
Dairy	9.28%
Chemicals	8.12%
Plastics and Synthetics	7.54%
Meat & Poultry	7.04%

All other industries show percentages of less than 5 percent for this statistic.

The ratio of total industrial plant expenditures for water pollution control (not including payments to municipalities for water pollution control) to total output again are much smaller percentages than those for investment. The most highly impacted industries using this statistic are:

Leather Tanning	3.58%
Fabricated Metals & Electroplating	3.25%
Chemicals	3.24%
Pulp & Paper	1.98%
Machinery	1.73%
Canned & Frozen Food	1.61%

All other industries show percentages of less than 1.5 percent. As for air pollution control, the relative capital-intensity of pollution control costs for various industries causes the ranking of industries in this list to shift from the order of the previous list.

A final consideration in impact evaluation is the total impact of the combination of air and water pollution control costs. Altogether, nine aggregate industries will require an investment level for pollution control over the decade that is more than 9 percent of other planned investment in each industry:

Leather Tanning	68.43%
Grain Milling & Feed Mills	15.56%
Canned & Frozen Food	15.48%
Fabricated Metals & Electroplating	15.21%
Pulp & Paper	14.20%
Machinery	12.12%
Electric Utilities	10.44%
Chemicals	9.77%
Dairy	9.28%

Leather Tanning is by far the most impacted industry according to this statistic, with pollution control investments equal to slightly more than two-thirds of other planned investment over the decade.

All industries have a total pollution control cost as a percentage of sector output that is less than 5.0 percent. The most heavily impacted are:

Pulp & Paper	4.67%
Chemicals	4.29%
Electric Utilities	4.04%
Iron & Steel	3.62%
Leather Tanning	3.58%
Fabricated Metals & Electroplating	3.25%
Nonferrous Metals	2.79%
Asbestos, Clay, Lime, & Concrete	2.42%

The other industries are impacted at less than 2 percent of their total decade output.

COMPARISON OF SEAS INVESTMENT ESTIMATES FOR AIR POLLUTION CONTROL WITH ESTIMATES OF BEA

The year-by-year estimates of air pollution control investment presented in Chapter 4, which are necessary to equip over half of the existing plants with required pollution control devices by the beginning of 1976 and to equip all existing plants with such devices by the end of 1978, appear to be optimistic when compared with the Bureau of Economic Analysis (BEA) estimastes of actual air pollution investment expenditures in 1973 and 1974 and of planned expenditures for 1975. Table 1 compares common estimates for both studies, showing BEA estimates of actual air pollution investments as a percentage of the SEAS forecast of investments for the three years.

Table 1.
Comparison of SEAS Forecast Investments and BEA Estimates of Actual Air Pollution Investment Expenditures for 1973, 1974, and 1975
(BEA estimates as a percent of SEAS Forecasts)

	1973	1974	1975	1973-1975
All Industries	105%	69%	38%	57%
Electric Utilities	182%	139%	123%	141%
Ferrous Metals	24%	16%	19%	19%
Nonferrous Metals	129%	49%	46%	63%
Stone, Clay, Glass	43%	47%	32%	39%
Food	32%	17%	17%	20%
Paper	45%	49%	60%	52%
Chemicals	155%	105%	106%	118%
Petroleum	184%	142%	369%	144%

In analyzing Table 1, note that according to SEAS forecasts of investments, industries in aggregate were spending about the right amount in 1973 (as estimated by BEA). Ferrous Metals; Food; Stone, Clay, and Glass; and Paper, however, were well behind schedule even at this point. By 1974, the total for all industries had slipped behind the pace estimated by SEAS as required to meet the pollution standards. Possibly as an aftermath of the economic recession, attempts to fight Federal regulations in the courts, or other factors, industries as a whole had dropped to less than 70 percent of the expenditure level needed in 1974. Ferrous Metals and Food dropped even further behind their respective schedules than they were in 1973. By 1975, the expenditures planned by industries had dropped to only slightly above a third of the amount needed to meet the expenditure schedule of the Reference Abatement Scenario. However, three industries (Electric Utilities, Chemicals, and Petroleum) planned to install more equipment than the SEAS investment schedule estimated as being needed. For example, Petroleum planned to spend at a level three and a half times greater than estimates indicated would be needed by 1975 to meet the compliance schedules discussed in Appendix B. A fourth sector, Paper, does not achieve the required investment pace during 1973 through 1975, but it does improve its percentage over time. In contrast to these industries, the other four industries in Table 1 exhibit declining investment schedule percentages over the full time period and are at less than 50 percent of required investment by 1974. These industries are Ferrous Metals; Nonferrous Metals; Stone, Clay, and Glass; and Food.

ESTIMATING SIGNIFICANT ENVIRONMENTAL CONTROL COSTS

Four types of environmental control costs are estimated by SEAS. These types, along with the receiving medium associated with each, are:

- Industrial (air and water)
- Mobile sources (air)
- Municipal (water)
- Government (air and water)

The techniques used to develop cost estimates for each of these types are presented in the following discussion.

Estimating Air and Water Costs for Industrial Sources

All of the industrial control costs estimated by SEAS (except for Electric Utilities) are endogenously determined. These industrial costs are calculated using characteristics of existing plants and estimated characteristics of new plants to be built in response to overall economic activity forecast by the SEAS economic projections. Therefore, if one scenario has a 10 percent higher GNP than another by 1985, it will consequently forecast more new plants and higher pollution abatement costs. This factor explains a great deal of the differences between the Reference Abatement Scenario costs and previous estimates by EPA and other agencies. In addition, the composition of, as well as the amount of, GNP growth affects the industrial cost estimates. Further detail on the industrial cost estimation techniques is provided in Appendix D.

Three additional types of environmental control costs besides industrial costs are important. These are the costs associated with mobile sources, municipal treatment, and governmental expenditures. These costs are determined outside the dynamics of the SEAS economic forecasting models, but are made consistent with the results of these models and, consequently, the industrial cost estimates. For example, the control costs associated with new automobiles are very much dependent upon the forecast of new car sales. When national conditions change in such a way as to alter the baseline projection of new car sales from 1971 to 1985, the inputs to the mobile source control cost calculations are correspondingly adjusted.

Estimating Air Costs for Mobile Sources

Mobile source air pollution control costs are generated as a result of emission standards for light-duty vehicles (LDV), heavy-duty vehicles (HDV), and aircraft, plus the impact of State Transportation Control Plans (TCP's). The Clean Air Act specifies national standards for mobile source emission levels for hydrocarbons, carbon monoxide, and nitrogen oxides.

The costs to reach the national standards for emission levels by the target years contined in the Clean Air Act are estimated by a model that ages the present stock of vehicles, year by year. The model takes into account new vehicle sales, which are based upon the GNP and personal income figures provided by the scenarios discussed in the macroeconomic analyses. Calculated mobile source control costs for the entire stock of vehicles are then fed back through the interindustry model. For example, the capital expenditures for automobile control devices are treated as additional expenditures for the Motor Vehicles and Parts sector while the operation and maintenance (O&M) expenditures are treated as additional expenditures for the Auto Repair sector.

The mobile source costs calculated in this comprehensive analysis reflect meeting the stringent standards (0.41 HC, 3.4 CO, 0.4 NOx) and subsequent administrative postponements. Costs presented in Section 2 were recently updated to reflect further postponements proposed in Clean Air Act amendments of Summer 1977.

Concentrations of carbon monoxide and smog (caused by hydrocarbons and nitrogen oxides reacting in sunlight) are so high in several metropolitan areas that even the stringent stationary source controls and the Federal mobile source emission standards do not reduce emissions sufficiently to meet Federal ambient air quality standards. These areas have developed Transportation Control Plans (TCP's) that involve combinations of additional mobile source controls (more retrofit devices for existing vehicles, strong inspection and maintenance measures, and vapor control systems for gas stations).

The TCP costs (not adjusted to reflect savings from improved fuel economy) are estimated to be $0.7 billion over the 1976-85 period. Most of these costs are for inspection and maintenance of automobiles to insure that their pollution control devices are operating at the proper effectiveness. These are expenditures made primarily by automobile owners. However, increased engine maintenance results in significant fuel economy, which is a direct economic benefit to automobile owners. In offsetting the increased maintenance costs with these fuel savings, only a small net total cost of $0.1 billion is left for TCP's over the 1976-85 period. (Refer to Section 2, Transportation Control Plans, for further detail.)

Estimating Water Costs for Municipal Treatment

Municipal water pollution control expenditures comprise the largest single category of water pollution control expenditures. Municipal expenditures are divided into six types:

- Construction of sewage treatment plants to provide secondary treatment

- Construction of sewage treatment plants to provide tertiary treatment more stringent than secondary treatment (removal of phosphorus, ammonia, nitrates, and organic pollutants)

- Rehabilitation of old sewers

- Construction of new sewers

- Correction of overflow from combined storm and sanitary sewers

- Provision for stormwater treatment

Federal funds spent for municipal treatment are based upon past levels of expenditures and the present funding authority of $19.5 billion for municipal construction grants to states. State-local matching capital expenditures are expected to be a third of the Federal construction grant (i.e., Federal funds will comprise about 75 percent of construction expenditures). Annualized capital expenditures are estimated to be $46.0 billion over the 1976-85 period. O&M expenditures to be made by state and local governments are estimated to be $16.0 billion over the same period. Very recent estimates (see Section 2) have slightly modified these totals.

Estimating Air and Water Abatement Costs to Government

Estimates of governmental expenditures for air pollution were made by using Office of Management and Budget (OMB) estimates of Federal expenditures and by calculating state and local expenditures through extrapolation of data for 15 sample states for which estimates of the costs of the State Implementation Plans were available.

The governmental water control costs exclude Federal and state and local government expenditures for municipal treatment (covered elsewhere under the Municipal Expenditures title), but they do include expenditures for:

- Monitoring

- Technical assistance

- Grant assistance

- Research

- Abatement at government-owned facilities.

The total governmental expenditure for pollution control is estimated to be over $12 billion during the next decade. The expenditure for any year is never as high to one percent of the total estimated annual non-defense governmental expenditure, during the 1976-85 period.

ESTIMATING POLLUTION CONTROL COST IMPACTS

Previous estimates of the cost of air and water pollution control by EPA have been presented in separate reports, The Cost of Clean Air and The Economics of Clean Water. In these reports, costs were computed separately on an industry-by-industry basis for air and water and then summed to arrive at a total pollution control cost for air and water, respectively. The two reports, however, often differed in such assumptions as the growth in industrial capacity which would be subject to controls and the rate of interest. In addition, no estimates were developed in either report on the combined impact of air and water pollution control expenditures on the economy in terms of increased construction, equipment purchases, operating materials, energy demand, and employment.

For this report, a consistent set of assumptions was developed and entered into SEAS for the computation of both air and water pollution control costs. Impacts were then estimated through the feedback of abatement-related purchases to the sectors that produce and sell those goods in the national economic forecasting model of SEAS. These feedbacks include direct impacts on the demand for abatement equipment and materials from supplying industries, as well as on abatement-related employment for operation and maintenance activities in the industries making the expenditures. Additional feedbacks were used to estimate the indirect effects of abatement costs on the capital required to finance construction and equipment purchases and on the amount of energy consumed. The estimated direct and indirect impacts resulting from these feedbacks are presented below.

Capital and O&M Impacts

Each air pollution device and each water pollution control technology has a capital and an O&M cost associated with it which can be treated as purchases of goods and services from selected sectors of the economy. For example, the three principal air pollution control devices for industrial sources - electrostatic precipitators (ESP), scrubbers, and fabric filters (baghouses) - have the capital and O&M feedback expenditure pattern shown in Table 2. The table shows that for every $100 of capital expenditure for precipitators, $48.90 goes to the New Construction sector, $19.00 goes to the Other Fabricated Metal Products sector, $10.00 goes to the Industrial Controls sector, $8.00 going to the Cement, Concrete, Gypsum sector, and so on down to $0.10 goes to the Paints Sector and to the Other Stone and Clay Products sector. Similarly, for every $100 in non-labor O&M spent on precipitators, $56.70 goes for maintenance, $42.80 goes for electricity and $.50 goes for paint materials.

When the full set of feedback matrices shown in Table 2 are examined, one can get an a priori indication of which industries will be impacted positively (via increased sales) as a result of the pollution control expenditures. It appears that New and Maintenance Construction, as well as Electric Utilities, will experience significant positive impacts as a result of investment and O&M expenditures for air pollution control.

Table 2.
Feedback Relationships for Three Common Air Pollution Control Technologies

	Precipitators		Wet Scrubbers		Filters	
Sectors	Capital	Non-Labor O&M	Capital	Non-Labor O&M	Capital	Non-Labor O&M
New Construction	48.9		52.0		49.4	
Maintenance Construction		56.7		28.7		61.5
Industrial Chemicals				0.1		
Cellulosic Fibers					1.5	2.0
Noncellulosic Fibers					3.5	4.0
Paints	0.1	0.5	0.1	0.5	0.1	0.5
Structural Clay Products			1.0		1.2	
Cement, Concrete, Gypsum	8.0		1.7		7.3	
Other Stone & Clay Prod(Asbestos)	0.1		0.1		0.1	
Aluminum	0.5				0.3	
Plumbing & Heating Equip	2.9		6.7		0.7	
Structural Metal Products	4.7		3.1		4.8	
Pipes, Valves, Fittings	1.0		3.5		1.3	
Other Fabricated Metal Prod	19.0		12.6		19.2	
Material Handling Machinery	1.5		3.0		1.2	
Pumps, Compressors, Blowers	1.8		6.7		3.5	
Motors and Generators	0.5		1.6		0.9	
Industrial Controls	10.0		4.0		4.0	
Elec Lighting and Wiring Equip	1.0		4.9		1.0	
Electric Utilities		42.8		41.5		32.0
Water and Sewer Services				29.2		

To examine the feedback impacts on the key sectors listed in Table 2, the output of those sectors for several years is compared for the Reference Case scenarios with abatement and without abatement. As Table 3 shows, capital feedbacks affect industries most heavily prior to 1985, whereas the O&M feedbacks are strongest in 1980 and 1985 when most plants will be in compliance with air and water regulations.

Table 3.
Percent Increase in Output with Addition of Abatement to the Reference Case

Sectors	1975	1980	1985
New Construction	14.94	6.15	1.21
Maintenance Construction	3.02	3.06	2.92
Cement, Concrete, Gypsum	12.78	3.41	0.76
Plumbing & Heating Equip	11.46	0.59	0.72
Structural Metal Products	8.01	2.94	0.91
Pipes, Valves, Fittings	21.41	16.94	2.45
Other Fabricated Metal	22.64	2.67	0.79
Pumps,Compressors,Blowers	7.33	0.71	-0.11
Industrial Controls	22.34	1.13	0.40
Electric Utilities	3.17	3.80	3.20
Water and Sewer Services	2.25	3.57	2.98

These estimates should be viewed as projections of what would have to happen if the assumptions about the timing of pollution control expenditures specified in Appendix B are accepted. Specific sectors of the economic system may not actually be able to absorb the amount and timing of pollution investment shown to be necessary to meet the compliance schedules with the control procedures discussed in Sections Two and Three.

Employment Impacts

By the year 1985, the level of employment required for pollution control activities of the nation's industries and municipal waste treatment facilities is estimated at 445 thousand employees. The breakdown by pollution control category is as follows:

Total Direct Pollution Control Employment (1985)	Thousands of Workers
Total Direct Pollution Control Employment (1985)	445.2
Air Pollution Control	19.5
Water Pollution Control	425.7
Municipal	59.2
Industrial	366.5
Machinery, Equipment, & Fabricated Metals	220.1
Organic Chemicals	30.0
Electroplating	20.5
Other	95.9

To provide an insight to the buildup of employment being used for operation and maintenance of pollution control equipment, the O&M employment levels for selected years are listed below:

Total O&M Employment	Thousands of Workers			
	1977	1980	1983	1985
Industrial Air Pollution Control	16.5	21.0	20.3	19.5
Industrial Water Pollution Control	150.3	211.1	237.9	366.5
Municipal Water Pollution Control	27.6	52.1	57.2	59.2
TOTALS	194.4	284.2	315.4	445.2

These levels of employment are calculated based on a detailed methodology for each specific industry and associated pollution control technologies that are operating in that year. For each technology, data concerning the amount of each O&M dollar spent includes the fraction spent for direct labor and the mean annual gross salary required, permitting determination of employment levels.

Other effects on employment levels exist due to pollution control actions besides the direct effects noted above. These include employment generated by purchases related to pollution control construction, equipment and materials, plus general impacts of the induced change in final demand and industry demand mix on the GNP and industrial outputs. For example, it was noted earlier that the introduction of pollution control equipment in the Reference Case caused outputs of some sectors (e.g., Machinery) to increase while dampening the outputs of others.

To assess the combined direct and indirect impacts of pollution control on employment, changes in employment must be compared to those for direct pollution control employment. Total employment at the national level in 1985 is about 245,900 persons greater for abatement than without abatement, but 445,200 workers of the total with abatement are engaged in operating and maintaining pollution control equipment. Therefore, about 199,200 fewer workers in 1985 are producing output that contributes to GNP based on present definitions. This occurs because the 445,200 workers who are working toward "producing a cleaner environment" are not counted as "producing goods and services" as conventionally defined in national economic accounts.

To compare direct and indirect employment impacts of pollution control over time, Table 4 below provides a listing of the change in employment between the Reference Scenario (S1) and the Reference Abatement (S2) Scenario for selected years.

Table 4.
Employment Changes Resulting from Pollution Controls
(Thousands of Workers)[1]

Year	Total Employment S1	Total Employment S2	Difference S2-S1	Total O&M Pollution Cntrl Employment
1977	90,266.4	91,892.2	1,625.8	194.4
1980	96,752.0	97,199.5	447.5	284.2
1983	100,893.5	101,328.7	435.2	315.4
1985	103,113.2	103,359.1	245.1	445.2

[1] S1 = Reference Scenario; S2 = Reference Abatement Scenario.

This table can be interpreted as follows: The difference between the two scenarios reflects the change in total employment due to the impact of pollution control on the general economy. A comparison of these figures with those shown in the last column indicates that the employment gains directly associated with pollution control dominate or exceed the more indirect employment effects in the later years. However, pollution control capital expenditures stimulating indirect employment are the primary factor causing increased total employment up to 1980.

Energy Impacts

The direct and indirect impacts of the air and water pollution controls on energy use can be determined by comparing the national energy consumption (in Btu's) in 1985 in the Reference Abatement Scenario (when controls are in place) with the energy consumption in 1985 for the Reference Scenario (with approximately the same 1985 GNP but no incremental abatement controls past 1971). This comparison, presented by consumer class in Table 5, reveals that total consumption increased by 4.13 percent with increased abatement controls. Almost half of this increase comes in the use of energy by electric utilities, which shows a net increase of 5.40 percent.

Among industrial energy users in 1985, Industrial Chemicals accounted for the largest portion of the net increase of 3.57 percent. Other large increases in energy use were registered by Steel, Aluminum, and Petroleum. Several industries increased their electricity consumption dramatically when pollution abatement was adopted by all industries. For example, Chemicals increased its electricity consumption by 89 perent, Phosphate Fertilizer by 71 percent, Aluminum by 31 percent, Steel by 19 percent, and Plastics by 19 percent.

Table 5
Increase in Energy Consumption with Addition of Abatement to the Reference Case

Consumer Class	1985 Energy Use[1] (Trillions of Btu's) S1	S2	Percent Change (S2-S1)/S1 x 100
Industrial	26,058.8	26,989.9	3.57
Transportation	24,635.8	25,669.6	4.20
Commercial	7,425.1	7,411.6	-0.19
Residential	9,779.5	10,108.3	3.36
Electric Utilities	41,110.2	43,328.7	5.40
TOTALS	109,009.3	113,507.4	4.13

[1] S1 = Reference Scenario; S2 = Reference Abatement Scenario.

Ranking of Sectors by Degree of Economic Change

A final measure of pollution control cost impacts is the relative effects among economic sectors. Economic data used to assess these impacts include outputs, construction expenditures, capital investments, and personal consumption expenditures. Changes in these data for various sectors in going from the Reference Scenario to the Reference Abatement Scenario are given in Table 6 for the forecast years of 1977, 1980, 1983, and 1985.

In Table 6(A), the 10 industries with the greatest percentage increase in output when comparing the Reference Abatement Scenario to the Reference Scenario are given. The different impacts of capital investment and O&M purchases for pollution control during the four years can be noted in the rankings and the percentage changes. For example, the timing requirements for capital expenditures for pollution control equipment are evidenced by the New Construction sector being stimulated by 13.0 percent in 1977 and then dropping to 6.2 percent in 1980, 3.3 percent in 1983, and

1.2 percent in 1985. A contrasting pattern is provided by a major O&M materials supplier, Industrial Chemicals. This sector is ranked eighth in 1977 (9.9 percent) but rises to third in 1980 (9.5 percent), second in 1983 (9.4 percent), and first in 1985 (10.2 percent). Sectors associated with the extraction of energy ores and sales of energy show trends similar to Industrial Chemicals. Similarly, the peaking and dropoff in ranking of equipment fabrication sectors is consistent with the New Construction sector pattern. For example, note the values and ranks for Pipes, Valves and Fittings, Special Industrial Machinery, and Electric Lighting and Wiring Equipment.

The converse of positive output impacts are provided in Table 6(B), which shows the six industries suffering the greatest percentage decrease in outputs for each year. The general categories impacted are mass transit equipment, minor transportation equipment, and personal clothing items. The level of impact for these sectors is much less than the level of impact for stimulated industries. During the late 1970's, the greatest negative impact is only one-third of the tenth greatest positive impact. For 1983, the level of negative impacts for the six industries is much higher than the level found in 1977 and 1980; yet even then the largest negatively impacted industry is impacted slightly less than the tenth largest positively impacted industry.

Turning to pollution control cost impacts on construction, Table 6(C) provides a ranking of the construction industries that are most stimulated or depressed for the four years. The sector of Water Systems Construction is high-ranked throughout the period. The increased demand for energy to meet pollution control standards is reflected in the increasing demand for Gas Utilities and Pipeline Construction and Electric Utility Construction through 1985. The early combined demand for air pollution and water BPT pollution controls cause Industrial Construction to be ranked third in 1977. However, later output decreases for some industries cause Industrial Construction to show minor declines from 1980 on. In addition, Telephone Construction is somewhat depressed in 1980 and 1983.

To examine the positive stimulus on capital equipment investment, Table 6(D) shows those industries with greatest percentage increases for capital investment. The highest-ranked industries for each year are usually industries that would provide equipment and/or maintenance products for pollution control. Therefore, for each of the four years, equipment industries appear in the top four: Motor Vehicles and Parts, and Hardware & Platings.

Finally, Tables 6(E) and 6(F) provide the major impacted sectors in terms of percentage change in personal consumption expenditures (PCE). Table 6(E) lists all sectors having an increase of greater than 1 percent for the four years. For all four years, only four sectors achieve this level: Trucking Services, Natural Gas Sales, Auto Repairs, and Petroleum Refining. Table 6(F), on the other hand, shows the five greatest negatively impacted sectors for PCE's, given that the sector has an annual PCE value of over 100 million dollars. Three sectors occur in all four years: Buses and Local Transit Services, Pottery, and Cycles and Minor Transporation Equipment. Other products represented in this negatively impacted group are other transportation services and, in the 1980's, clothing products. Thus, the negatively impacted sectors for total output (Part B of Table 6) and for PCE are generally consistent.

Table 6.
Sectors Ranked by Greatest Percent Change in Economic Variables Between Reference Abatement Scenario and Reference Scenario

A. Greatest Percentage Increase in Output

1977		1980		1983		1985	
Pipes, Valves, Fittings	19.3	Pipes, Valves, Fittings	16.9	Pipes, Valves, Fittings	11.0	Industrial Chemicals	10.2
Special Industrial Machinery	15.3	Special Industrial Machinery	12.1	Industrial Chemicals	9.4	Crude Petroleum Natural Gas	8.0
Structural Clay Products	13.7	Industrial Chemicals	9.5	Crude Petroleum Natural Gas	7.3	Natural Gas	7.5
New Construction	13.0	Crude Petroleum Natural Gas	6.5	Special Industrial Machinery	6.8	Auto Repair	7.1
Other Fabricated Metal Products	12.5	New Construction	6.2	Auto Repair	6.6	Chemical Fert. Mining	6.3
Cement, Concrete Gypsum	12.1	Chemical Fert. Mining	5.6	Natural Gas	6.1	Pipelines	6.2
Industrial Controls	11.9	Auto Repair	5.6	Chemical Fert. Mining	5.7	Complete Guided Missiles	4.4
Industrial Chemicals	9.9	Elec. Lighting and Wiring	5.5	Pipelines	5.7	Lead	4.2
Elec. Lighting and Wiring	9.1	Natural Gas	5.2	Complete Guided Missiles	4.6	Petroleum Refining	4.1
Lumber and Wood Products	7.9	Pipelines	5.1	Misc. Chemical Products	4.2	Misc. Chemical Products	4.0

Table 6. (Continued)
Sectors Ranked by Greatest Percent Change in Economic Variables
Between Reference Abatement Scenario and Reference Scenario

B. Greatest Percentage Decrease in Output (Continued)

1977		1980		1983		1985	
Cycles, Minor Trans. Equipment	-1.0	Construction, Mining Oil Field Machinery	-2.6	Construction, Mining, Oil Field Machinery	-3.9	Buses and Local Transit	-3.6
Buses and Local Transit	-0.8	Buses and Local Transit	-2.5	Buses and Local Transit	-3.4	Constr., Mining Oil Field Mach.	-3.4
Apparel	-0.8	Railroad Equipment	-2.5	Machine Tools, Metal Forming	-2.9	Apparel	-2.1
Footwear	-0.7	Cycles, Minor Trans. Equipment	-2.1	Railroad Equipment	-2.3	Machine Tools, Metal Forming	-2.0
Leather and Ind. Leather Products	-0.4	Apparel	-2.1	Machine Tools, Metal Cutting	-1.8	Cycles, Minor Trans. Equip.	-1.6
Knitting	-0.4	Jewelry and Silverware	-1.8	Cycles, Minor Trans. Equipment	-1.6	Footwear	-1.6

C. Greatest Percentage Changes in Construction Sectors

1977		1980		1983		1985	
Sewer Systems	170.1	Water Systems	58.5	Water Systems	23.6	Water Systems	17.0
Water Systems	107.5	Sewer Systems	39.1	Gas Utilities and Pipelines	5.2	Gas Utilities and Pipelines	6.8
Gas Utilities and Pipelines	9.2	Gas Utilities and Pipelines	6.2	Electric Utilities	2.9	Electric Utilities	3.0
Industrial	3.1	Electric Utilities	3.4	Telephone	-1.0	Industrial	-0.9
Electric Utilities	2.7	Telephone	-1.7	Industrial	-2.1		
Telephone	1.2	Stores, Restaurants, and Garages	-1.8				
Hotels, Motels, and Dormitories	-0.1	Industrial	-2.2				

Table 6. (Continued)
Sectors Ranked by Greatest Percent Change in Economic Variables
Between Reference Abatement Scenario and Reference Scenario

1977		1980		1983		1985	
D. Greatest Percentage Increase in Capital Investment							
Hardware, Plating	161.5	Hardware, Plating	129.5	Engineering and Scientific Instru.	85.0	Hardware, Plating	29.1
Engineering and Scientific Instru.	76.0	Motor Vehicles and Parts	114.3	Hardware, Plating	83.1	Motor Vehicles and Parts	17.7
Motor Vehicles and Parts	71.8	Engineering and Scientific Instru.	106.5	Motor Vehicles and Parts	58.1	Industrial Chemicals	14.3
Industrial Chemicals	66.1	Canned and Frozen Foods	53.8	Canned and Frozen Foods	37.7	Canned and Frozen Foods	13.4
E. Greatest Percentage Increase in PCE (all sectors > 1.0%)							
Trucking Services	33.7	Trucking Services	46.6	Trucking Services	56.3	Trucking Services	61.8
Auto Repair	9.8	Auto Repair	9.1	Auto Repair	11.0	Auto Repair	12.0
Petroleum Refining	5.2	Petroleum Refining	5.3	Petroleum Refining	6.4	Petroleum Refining	7.0
Natural Gas	3.8	Natural Gas	4.4	Natural Gas	5.0	Natural Gas	5.3

Table 6. (Continued)
Sectors Ranked by Greatest Percent Change in Economic Variables Between Reference Abatement Scenario and Reference Scenario

1977		1980		1983		1985	
F. Greatest Percentage Decrease in PCE (PCE for sector > 100M$)							
Railroads	-2.8	Buses & Local Trans.	-4.6	Buses & Local Trans.	-5.9	Buses & Local Trans.	-6.0
Buses & Local Trans.	-2.7	Non-Competitive Imports	-3.1	Cycles, Minor Trans. Equipment	-2.5	Pottery	-2.6
Pottery	-1.8	Pottery	-3.1	Pottery	-2.2	Cycles, Minor Trans. Equipment	-2.5
Cycles, Minor Trans. Equipment	-1.8	Cycles, Minor Trans. Equipment	-2.4	Footwear	-1.9	Apparel	-2.2
Glass	-1.0	Apparel	-2.1	Airlines	-1.8	Footwear	-2.1

THE DYNAMIC NATURE OF TOTAL POLLUTION CONTROL EXPENDITURES

Earlier in this analysis, the costs to control air and water pollution were stated in terms of dollars expended over a relatively short time period, 1976-1985. The amount and timing of expenditures during the next 10 years is important, but the impression should not be left that total expenditures decline radically after the first round of investments in pollution equipment.

Figure 1 shows investment and total annual costs (annualized capital plus O&M) for air and water pollution control in the Reference Abatement Scenario. Although the year-by-year expenditures are assumptions, the general trends of the lines are reasonable estimates of expenditures, given the overall assumptions of the Reference Abatement Scenario.

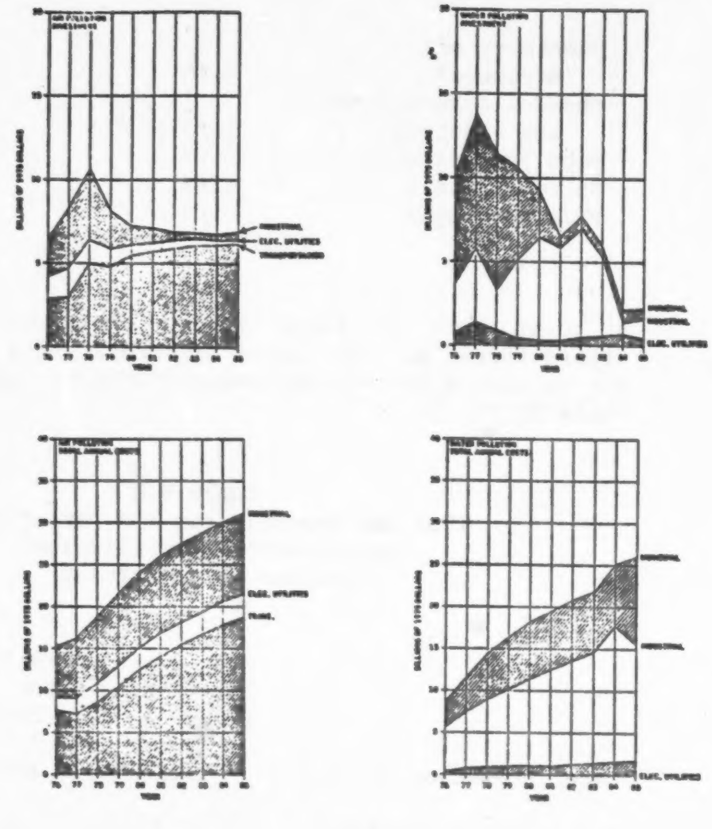
Table 7 shows the annual capital and O&M expenditures required of the industrial sector from 1972-1985. Note that in the case of air investment expenditures, Electric Utilities and other industrial sources demonstrate a peaking of capital expenditures during the 1973-78 period with very small annual increments to investment expenditures by 1985. The total annual costs for stationary sources also grow and then level off after 1980. No such leveling off is witnessed for water pollution total annual costs, but this might occur just a few years beyond 1985 since effluent regulations after 1983 may require lower increases in pollution costs after 1985.

Table 7.
Industrial Sector Annual Pollution Control Expenditures
(Billions 1975 Dollars)[1]

	Air		Water		Total	
Year	Annual. Capital	O&M	Annual. Capital	O&M	Annual. Capital	O&M
1972	0.5	0.4	-	-	0.5	0.4
1973	1.3	1.0	-	-	1.3	1.0
1974	2.5	1.8	0.7	1.2	3.2	3.0
1975	3.6	2.8	1.6	2.7	5.2	5.5
1976	4.0	3.5	2.1	3.6	6.1	7.1
1977	4.7	4.1	3.0	4.8	7.7	8.9
1978	5.5	4.6	3.6	5.9	9.1	10.4
1979	5.9	5.0	4.4	6.4	10.3	11.4
1980	6.1	5.2	5.4	6.9	11.5	12.1
1981	6.3	5.3	6.3	7.3	12.6	12.6
1982	6.5	5.3	7.2	7.5	13.6	12.9
1983	6.5	5.3	7.9	7.9	14.4	13.2
1984	6.6	5.3	8.0	11.1	14.7	16.4
1985	6.7	5.3	8.2	11.5	14.9	16.8

[1] Parts may not sum to total because of rounding.

Figure 1.
Annual Investments and Total Annual Costs for
Air and Water Pollution Control, 1976-1985



Considering O&M expenditures alone, these expenditures for industries are approximately $16.8 billion by 1985 for air and water pollution control combined (see Table 7). Water O&M expenditures make up the largest part of this total, 69 percent. The industrial sectors making the largest water pollution control O&M expenditures in 1985 are:

	O&M Expenses (Billion 1975$)	Percent of Total Industrial Water O&M
Machinery and Equipment	6.45	55.9
Chemicals,Fertilizers and Plastics	1.83	15.8
Food Processing	0.77	6.7
Ferrous Metals	0.68	5.9
Pulp and Paper	0.61	5.3

A great part of these water pollution control O&M expenditures go for labor expenses. This is not true for air pollution control O&M expenditures however, as shown in Table 8.

Table 8.
1985 O&M Expenditures and Direct Labor Requirements for Pollution Control by Industries

	O&M (Billions 1975$)	Direct Labor (1,000's)	Employees/ Million $
Water Pollution Control	11.5	389	33.83
Air Pollution Control	5.3	20	3.77

Based on these figures, the average water pollution control O&M expenditures in 1985 are stimulating direct employment of 33,830 jobs per billion dollars of water pollution control O&M expenditure. At the same time, the average air pollution control O&M expenditures are creating 3,770 jobs per billion dollars of air pollution control O&M expenditures. These figures give some idea of the potential employment impacts of O&M expenditures, which will continue beyond 1985.

Appendix A
The SEAS System

SEAS is a system of interdependent models and computer programs developed by EPA to assess the future economic and environmental consequences of Federal pollution control policies. Structurally, the system consists of a number of special-purpose models linked to the University of Maryland's INFORUM, an interindustry input-output model of the economy. The INFORUM model develops economic forecasts through 1985 based on alternative sets of demographic and macroeconomic assumptions specified by the user. In turn, these forecasts form the basic economic inputs used by the other models in SEAS to develop their more specialized forecasts.

A generalized overview of the SEAS system is presented in Figure A-1. As indicated by the dashed-lined box, two special-purpose SEAS models have been integrated into a common program with INFORUM: INSIDE, which provides greater detail on industrial sector output, and ABATE, which contains cost functions for abatement technologies. Together, these three models form the national economic forecasting program for the SEAS system. This program is fed by two data bases: one contains economic and pollution abatement costs data; the other, data on commodity relative prices. A feedback loop between the national economic program and the PRICES model allows relative price adjustments to be reflected in the SEAS economic forecasts. The final output file, containing annual economic and abatement cost forecasts through 1985, provides input data for six other special-purpose SEAS models:

- RESGEN - Estimates the annual tonnage of pollutant residuals from various industrial sources.

- PTRANS - Estimates the passenger transportation activity levels and residuals.

- FTRANS - Estimates the freight transportation activity levels and residuals.

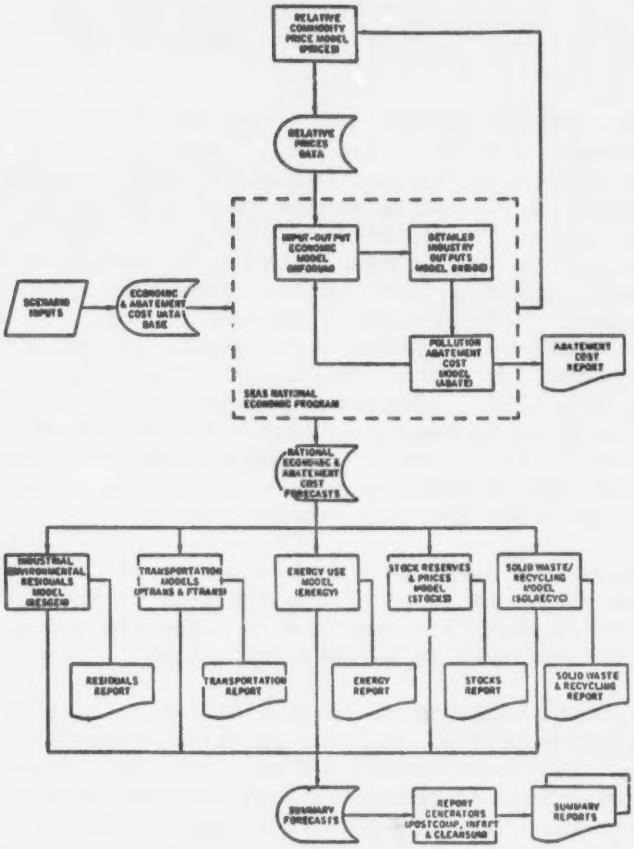
- ENERGY - Develops forecasts of energy consumption by consumer class and fuel category.

- STOCKS - Provides information on the price and availability of critical virgin stocks.

- SOLRECYC - Estimates the annual tonnage of solid waste and recycled materials.

Summary output from these six models, as well as the national economic program, is then collected in a common file for the production of summary reports.

Figure A-1.
Generalized Flowchart for the Strategic
Environmental Assessment System (SEAS)
(As Applied for this Report)


RELATIVE COMMODITY PRICE MODEL (PRICES)
RELATIVE PRICES DATA
INPUT-OUTPUT ECONOMIC MODEL (INFORUM)
DETAILED INDUSTRY OUTPUTS MODEL (INSIDE)
SCENARIO INPUTS
ECONOMIC & ABATEMENT COST DATA BASE
POLLUTION ABATEMENT COST MODEL (ABATE)
ABATEMENT COST REPORT
SEAS NATIONAL ECONOMIC PROGRAM
NATIONAL ECONOMIC & ABATEMENT COST FORECASTS
INDUSTRIAL ENVIRONMENTAL RESIDUALS MODEL (RESGEN)
TRANSPORTATION MODELS (PTRANS & FTRANS)
ENERGY USE MODEL (ENERGY)
STOCK RESERVES & PRICES MODEL (STOCKS)
SOLID WASTE/ RECYCLING MODEL (SOLRECYC)
RESIDUALS REPORT
TRANSPORTATION REPORT
ENERGY REPORT
STOCKS REPORT
SOLID WASTE & RECYCLING REPORT
SUMMARY FORECASTS
REPORT GENERATORS (POSTCOMP, INFRPT & CLEANSUM)
SUMMARY REPORTS

A description of the major functions performed by each of the SEAS models shown in Figure A-1 is presented below. This discussion of SEAS models emphasizes the computation of abatement costs and their associated economic feedbacks as a subsystem of the overall model structure.

THE INTERINDUSTRY ECONOMIC FORECASTING MODEL(INFORUM)

The INFORUM model is a 185-sector input-output model which projects future economic activity using structural relationships between economic and demographic variables. These projections determine total demands for the outputs of 185 industrial sectors, and the model then allocates these demands to the specific markets, or buying sectors, to which these products are sold. Thus, the model differentiates between intermediate demands and final demands. Intermediate demands are generated by sales from one industry to other producing industries. Final demands consist of government expenditures, exports, imports (expressed as negative exports), purchases by consumers, changes in inventories, and savings and investment. These final demand components make up what is commonly referred to as the Gross National Product (GNP).

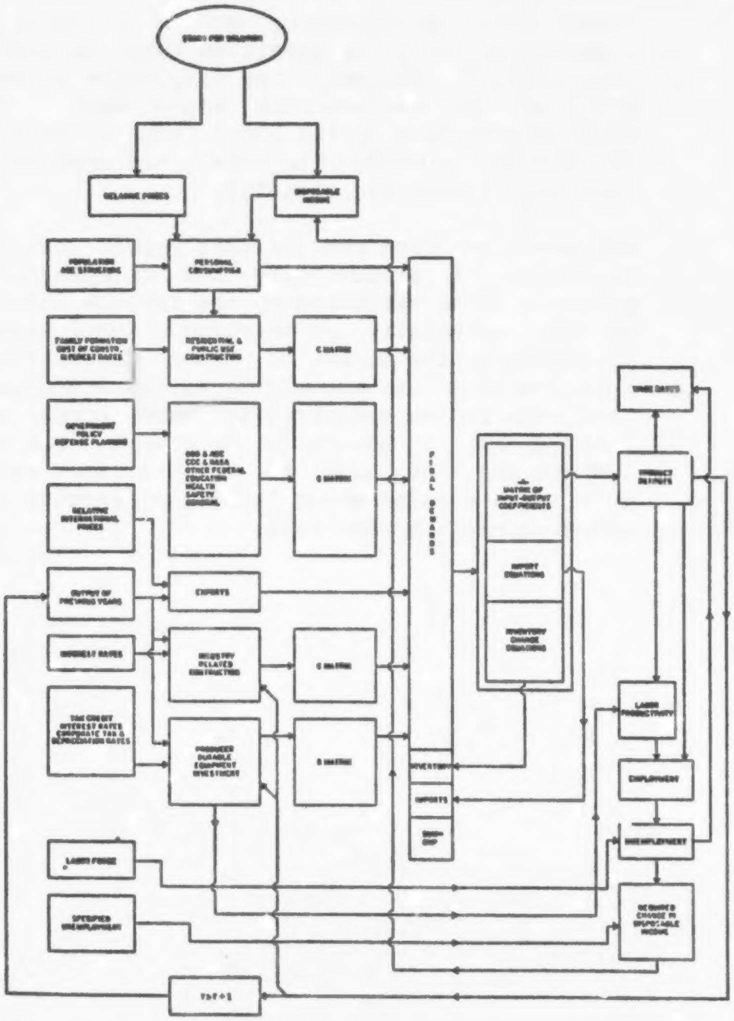
Figure A-2 displays a flow diagram of the INFORUM model. The column of boxes on the far left of the diagram represent factors which are specified outside the model. The solution procedure used is as detailed below.

A trial value of disposable income is coupled with a set of relative prices, allowing personal consumption expenditures to be calculated. These results, combined with the projections of households and interest rates, are used to determine expenditures for certain types of construction. Sales to construction investment by each industry are then determined by applying the C-matrix coefficients. In a similar manner, the sales by each industry to the government categories are determined by setting assumptions concerning government policy and defense planning into the G-matrix. Outputs of previous years and assumptions regarding the costs of capital are used to forecast investment in producer durable equipment and industry-related construction. Investment by industry is then determined by running these forecasts through the C- and B-matrices. This completes determination of total final demands.

The A-matrix of coefficients serves to convert total final demands to total product outputs by individual industries. Net imports and inventory changes for each industry are computed simultaneously. Labor productivities are then derived from changes in output and capital investment. Employment is determined by dividing the product outputs by labor productivity. If this result, when subtracted from labor force projections, yields a level of unemployment inconsistent with the specified input to the model (i.e., less than 4 percent), the disposable income assumption is modified and calculations begin anew. Otherwise, the outputs generated by the model, coupled with the projections of factors outside the model, are applied to forecast the next year's economic activity.

For most scenarios run for this report, official government forecasts of productivity and unemployment were used in place of those estimated by the INFORUM model and supplied by the University of Maryland. These higher productivity forecasts of the Bureau of Labor Statistics were entered into INFORUM exogenously. Personal disposable income was then adjusted as necessary in each scenario to calibrate unemployment to government forecasts. For these scenarios, INFORUM was thus used to compute the redistribution of intermediate sales among industrial sectors required to meet the government projections.

Figure A-2.
Flow Diagram of the Inforum Model with Solution Procedure



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THE SECTOR DISAGGREGATION
MODEL (INSIDE)

The INSIDE model performs two important functions: (1) it projects subindustry outputs at the level of detail required for environmental assessment; and (2) it forecasts changes in industrial growth due to technological substitution. INFORUM is an economic forecasting model which was not specifically designed to deal with environmental issues and detail. Hence, the different goods and services produced within any single INFORUM sector may have significantly different pollution or demand levels. Similarly, alternative processes may be available within a sector for producing the same material or product.

Special equations, termed side equations, are introduced by the INSIDE model to enable SEAS to account for environmentally-important product and process technology details not available directly from INFORUM. These equations disaggregate the annual sector outputs in dollars from INFORUM into annual outputs in physical units at a more detailed subsector level. For example, there are several hundred major chemicals embedded within INFORUM Sector 55, which projects economic activity for all industrial chemicals. However, the manufacture of nitric acid generates the vast majority of nitrogen oxide emissions produced by this industry. About 80 percent of the nitric acid manufactured is sold to fertilizers and miscellaneous chemicals, whereas Sector 55 sells over 50 percent of its general output to plastics, non-cellulosic fibers, cleaning and toilet preparations, miscellaneous chemicals, and paints. As a result the growth rate of nitric acid alone does not parallel the aggregate growth of all industrial chemicals in Sector 55. Thus, relating nitrogen oxide residual generation to nitric acid demand in other sectors rather than to the aggregate growth of Sector 55 gives a more accurate projection of nitrogen oxide emissions and control costs.

Technological substitutions in SEAS are treated in INSIDE by substitutions occurring among two to four alternative materials, processes, or products within a given industry. Examples of two-, three-, and four-way substitutions are presented below:

Table A-1.
Example of Technological Substitutions in SEAS

Type of Substitution	Commodity	Alternative Processes
2-Way	Chlorine	(1) Mercury Cell (2) Diaphragm Cell
3-Way	Steel	(1) Electric Arc (2) Basic Oxygen (3) Open Hearth
4-Way	Non-Nuclear Electric Utilities	(1) Coal (2) Oil (3) Gas (4) Other

The user specifies the substitution ratio for each material, product, or process as the fraction of a commodity produced by each alternative process. The rate of substitution based upon these initial fractions is also determined through user inputs. Thus, the INSIDE side equations can reflect the growth of the diaphragm cell manufacturing process for chlorine at the expense of the market share for the mercury cell process.

THE ABATEMENT COST AND FEEDBACK MODEL (ABATE)

The ABATE model estimates the investment costs and the operation and maintenance (O&M) costs associated with the control of air and water pollution for all significant polluting industries. It also provides feedback concerning the consequent increases in capital investments, employment requirements, consumption levels, and economic demands to INFORUM. The INFORUM model then uses this data to dynamically rebalance its forecasts of economic activity and produce revised estimates of such macrostatistics as GNP and unemployment, as well as relative shifts in interindustry demands and outputs.

The input data required by the ABATE model was compiled through research into the technological control options and their associated costs to meet environmental standards. The data used in the model corresponds directly to the industry-by-industry descriptions of abatement activity given in Sections Two and Three of this report. Some of the more important data inputs are discussed below:

1. All Categories Except Municipal Wastewater Treatment. The following data was developed for input to the ABATE model for all cost categories other than municipal wastewater treatment:

a. An inventory of plants, including size distribution of the total capacity of the industry category for a base year, was developed using the best information available from one or more of the following sources:

- Researcher files
- Trade associations
- Professional societies
- Directories of plants
- Periodic publications
- Government research documents.

b. Capital cost functions and O&M cost functions were specified for each standard (State Implementation Plans, Best Practicable Technology, Best Available Technology, and/or New Source Performance Standards). These functions relate cost to the physical measure of plant capacity used in the plant inventory. For industry categories involved in water pollution abatement, cost functions were developed for both the full in-plant treatment and pretreatment options.

c. For each industry category, capital and O&M costs were allocated as purchases from INFORUM sectors on the basis of the technology option(s) associated with the category.

d. The average life of the abatement equipment and a nominal interest rate of 10 percent were specified for each industry category to enable the model to calculate annualized capital costs.

e. Compliance years for each standard which applies to the industry category and also the year after which all new plant construction starts must meet New Source Performance Standards were specified.

f. The number of years over which capital expenditures for each standard are expected to be spread and the fractions of expenditures for each of these years were specified.

g. For industry categories involved in water pollution abatement, the percent of total capacity in each plant capacity class for each industry which discharges pretreated wastewater to municipal system was specified.

h. Annual investments and O&M costs for the control of air emissions from mobile sources and electric utilities were entered into the ABATE model exogenously for computation of feedback effects and aggregate air pollution abatement costs.

i. Pollution control costs reflect only abatement equipment and O&M expenditures in these simulations. Therefore, if a less polluting production process is adopted by an industry, a decrease in pollution control costs results.

2. **Municipal Wastewater Treatment Data.** The following data were developed as inputs to ABATE for municipal wastewater treatment (Municipal expenditures for this report were exogeneously expressed based on projected Government appropriations for sewage treatment facilities. The ABATE model was thus not used to calculate municipal costs, but the feedback features of SEAS were used to estimate the economic, employment, and energy impacts of these costs.):

a. Population served and per capita wastewater flow for each forecast year;

b. Capital and O&M cost functions for primary and secondary treatment and the cost functions for upgrading of secondary treatment;

c. Percent of wastewater flow to each treatment type and the average treatment plant size in each type;

d. Percent of total population whose wastewater needs are met either by replacement of previous treatment or by upgrading from primary to secondary or from secondary to tertiary, by year;

e. A similar collection of factors, percentages and cost curves for interceptor sewer costs, and for combined sewer overflow remedy costs; and

f. The wastewater flow generated by industies which divert their wastewater to municipal facilities for treatment.

The ABATE cost model uses the two types of data discussed above to generate aggregated abatement costs for each industry and for municipal treatment facilities in a straightforward manner, as follows:

1. Industrial Abatement Costs. The model forecasts yearly capacity for each industry using growth rates calculated from the corresponding INFORUM sector or subsector and initial plant capacity class data. The new capacity is distributed among the industry's plant capacity classes as specified by the user. Capital costs are then calculated for the average plant in each plant capacity class using the appropriate cost function (depending on the year and whether the plant must meet New Source Performance Standards). The model then sums costs across classes to get total capital costs for the year. For water categories, the model derives the costs using both the pretreatment and full treatment cost functions, depending on the fraction of capacity in each plant size class using municipal facilities. For these water categories, ABATE also calculates the total volume of wastewater discharged to municipal facilities, which is used to estimate investment recovery and user charges. Finally, the model uses equipment life and a 10 percent interest rate to annualize the capital costs.

ABATE performs a similar aggregation of O&M costs for industries. However, for existing plants, the expenditures do not begin until the compliance year is reached. Moreover, the model need not keep track of O&M expenditures spread over several years as it must do for capital costs. The O&M costs calculated by ABATE for a given year create a demand for resources that is reflected through feedbacks which modify the output levels for the affected INFORUM sectors. In turn, these changed output levels result in different sector growth rates, from which the abatement costs are recalculated for that year. ABATE and INFORUM are self-correcting as they use growth rates which are constantly being revised.

2. Municipal Abatement Costs. The municipal portion of ABATE calculates costs associated with building and upgrading treatment plants, with laying interceptor and collector sewer lines, and with the control of the combined sewer overflow problem. The new wastewater flow needing treatment in any year is based on incremental flow from industrial dischargers to municipal systems and that part of the non-industrial flow that needs replacement or upgrading. This new flow is allocated to treatment type (primary, secondary, or tertiary). Average plant sizes by type are then used to determine the number of new plants to be constructed. Capital and operating cost (minus the

operating cost of plants replaced) functions are used to determine total cost based on plants to be constructed and their average size. The amount of this cost to be fed back into INFORUM is adjusted by a user-specified factor indicating the proportion of this total not already accounted for in the INFORUM baseline. A similar procedure is used to determine costs for interceptors and collectors, and for correction of combined sewer overflow through use of incremental cost functions for these categories.

Annualized costs for municipal wastewater treatment are partially allocated back to an industrial source based upon the fraction of total wastewater flow it contributes. This fraction is applied against the O&M charges for municipal treatment to yield user charges. Municipal investment recovery is computed by applying this fraction to capital costs, with payment in equal annual installments over a 30-year period with no interest applied. Calculations of abatement expenditures for sewers and for the combined sewer overflow (CSO) problem is similar except that population needing sewers is distributed among city sizes, and population needing CSO correction is distributed among population groups. Hence, ABATE aggregate costs are computed by city size and by population group to obtain total expenditures for correcting the sewer and CSO problems, respectively.

For the pollution abatement scenarios run for this report, annual investments in municipal sewage treatment facilities were exogenously specified, based on the total projected funds available from Federal, state, and local governments. The computations of annualized municipal treatment costs and user charges were thus constrained by anticipated funding limitations.

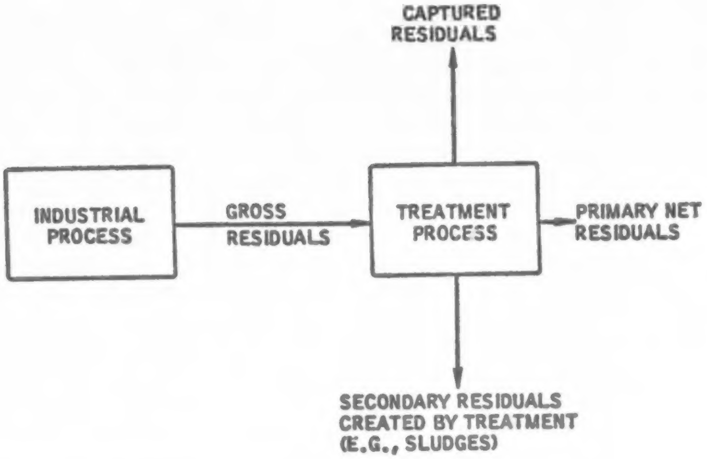
THE RELATIVE COMMODITY PRICE MODEL (PRICES)

The SEAS PRICES model, also adopted from the University of Maryland, provides INFORUM with relative indexes of prices among commodities. Two runs of INFORUM for each scenario are required to make use of the PRICES model. The first run of INFORUM produces a different distribution of inter-industry sales than that assumed in creating the original set of price indexes. The PRICES model is then run to generate a modified set of relative prices to be used by INFORUM. The model modifies prices of output from each sector based on time-lagged constant-price output for the sector, lagged unit material costs, and lagged unit labor costs. Abatement impacts on prices are included in the modifications as well as the impact of the redistribution of sales. Once the modified prices are determined, the INFORUM model is then rerun to provide a new forecast of the economy which takes into account the modified prices.

THE INDUSTRIAL ENVIRONMENTAL RESIDUALS MODEL (RESGEN)

RESGEN estimates the annual national pollutant residuals associated with industrial production, municipal treatment, and electric utility processes for six media: air, water, solid waste, leachates, pesticides, and radiation. It does not estimate motor vehicle emissions, storm water run-off residuals, or emissions from nonpoint sources of pollution (which consists of residuals associated with land use activities, such as agriculture, forestry, mining and drilling, and construction). Residuals for these three types of pollution are currently estimated outside of SEAS except for motor vehicle emissions, which are forecast by PTRANS and FTRANS. For all other significant polluting industries and utilities, RESGEN initially forecasts the gross pollutant emissions that would occur from each if no abatement activity had occurred pursuant to the 1970 Amendments to the Clean Air Act or the 1972 Amendments to the Federal Water Pollution Control Act. Then it estimates primary net residuals, assuming that some specified level of pollution abatement activity (including none) is occurring. The difference between gross residuals and net residuals for each industry is the captured residuals, which include recyclable wastes. RESGEN also generates estimates of significant secondary residuals produced by the pollution treatment processes themselves. (See Figure A-3.)

Figure A-3.
RESGEN Estimation Process Flowchart



As in the case of ABATE, the input data used by RESGEN corresponds directly to the pollution emissions reductions discussed in the industry summaries in Sections Two and Three for and water residuals. The primary data consists of gross residual coefficients for specified years and associated fractions of total wasteload treated, average removal efficiencies, and rates at which waste materials are recycled or converted to secondary residuals as percentages of captured residuals.

THE TRANSPORTATION MODELS
(PTRANS AND FTRANS)

The two transportation models, PTRANS and FTRANS, use annual forecasts of vehicle miles travelled by automobile, bus, truck, rail, commuter rail, and airplane to estimate the air pollution emissions for passenger and freight transportation vehicles in six residual categories: hydrocarbons, carbon monoxide, nitrogen oxides, sulfur oxides, lead, and particulates.

For a given calendar year, the PTRANS model uses the disposable income forecast from INFORUM and the population forecast to determine the number of new vehicles on the road. It uses data from the 1974 National Transportation Study for vehicle miles travelled by transportation mode and occupancy ratios to distribute the VMT forecast among intracity (auto, bus, rapid transit, railroad) and intercity (auto, air, bus, railroad) transportation modes. Then it uses EPA emissions factors to forecast net residuals for the year. In the case of automobiles, PTRANS also utilizes input data indicating the distribution of cars on the road by model year to forecast these residuals.

Freight ton-mile projections are computed by the FTRANS model by applying INFORUM growth rates for freight sectors to base year data for freight ton-miles drawn from Department of Transportation studies. Modal splits and weight loading factors are then applied to develop forecasts of vehicle miles travelled for trucks, rail, water, air, and pipelines. Pollutant emissions are then estimated by applying emission factors to each freight transportation mode. Again, these emissions represent net residuals.

THE ENERGY USE MODEL (ENERGY)

ENERGY estimates energy use by consumer class (industrial, commercial, residential, transportation, electric utility consumption, and electricity generation) and fuel category based on INFORUM annual output forecasts for the 185 economic sectors. For each fuel category, it also reports whether the fuel is used for combustion or as a raw material feedstock by the consumer class. The model provides a detailed accounting of all fuel usage in quadrillions (10^{15}) of Btu's based on the interindustry relationships in INFORUM at the time the sector output forecasts are made.

Because the energy forecasts are based on the INFORUM annual outputs, any supply constraints caused by relative price adjustments are introduced into the forecasts. The relative price adjustments might have resulted from changed fuel stock levels (STOCKS model) or from pollution abatement feedback into INFORUM (ABATE model). Consequently, ENERGY is sensitive to a wide range of conservation and abatement assumptions.

THE STOCKS RESERVES AND PRICES MODEL (STOCKS)

The STOCKS model in SEAS provides information on raw material sources, reserve levels, and relative production costs under alternative assumptions regarding import, export, and inventory levels. The model maintains accounts for both domestic and world-wide reserves as a function of relative production prices. Currently, twelve stock categories are included, of which six are fuels and six are non-fuel minerals. Overrides for prices, investments, imports, and exports concerning these stocks are generated by STOCKS as optional feedbacks to the national economic models.

THE SOLID WASTE AND RECYCLING MODEL (SOLRECYC)

The SEAS SOLRECYC model estimates the annual tonnage of solid waste generated from non-industrial sources, the expected proportional use of various disposal methods, and the costs associated with each disposal method. The model also projects estimated levels of recycling, which are fed to the STOCKS model for adjustment of raw material demands.

THE SUMMARY REPORT GENERATORS
(POSTCOMP, INFRPT AND CLEANSUM)

As shown in Figure A-1, each of the special-purpose models discussed above produces its own detailed output report. In addition to these detailed reports, summary data from these models, as well as from the national economic program, are collected in a common data file for production of summary reports. Three types of report generators were used to assist in the assessment of pollution control impacts:

- POSTCOMP, which provides annual data values and annualized percentage changes for significant parameters from every SEAS model, as well as comparative indexes for pollutant residuals produced by each of up to four scenarios;

- INFRPT, which provides comparative percentage differences and sector rankings in INFORUM economic results for selected scenario pairs; and

- CLEANSUM, which provides annual abatement costs and residuals for each SEAS economic sector.

Run books for the seven scenarios described in this Section are maintained on file at EPA. These books contain both the detailed model outputs as well as the summary reports produced for each scenario.

Appendix B
Scenario Assumptions

REFERENCE SCENARIO

The comparative scenario approach of Section Four requires that a set of assumptions constituting a baseline or Reference Scenario, be developed and used for comparative analysis of scenarios. The consequences of alternative assumptions concerning public policy can then be measured against this baseline. The purpose of the Reference Scenario is thus to establish a useful benchmark of general assumptions for comparative analysis; it is not intended to provide predictions of the most probable future.

The Reference Scenario for this study is based on assumptions about future trends and policies from 1976 through 1985. These assumptions, in general, represent official forecasts of the future made by appropriate government agencies in their specific areas of responsibility (e.g., population growth by the Bureau of the Census). Table B-1 presents the government agencies from which forecasts were obtained. Where appropriate, values for these forecasts are also given.

Table B-1.
Reference Scenario Assumptions

Assumption	Government Agency	Values
Population-Series E Projections (Millions of People)	Department of Commerce, Bureau of the Census	1975-213.9 1980-224.1 1985-235.7
Labor Force (Millions of People)	Department of Labor, Bureau of Labor Statistics	1975- 93.8 1980-101.8 1985-107.7
Labor Productivity	Bureau of Labor Statistics	Varies by Industry
Gross National Product (Trillions of 1975 Dollars)	Ford/Council of Economic Advisors (1975-1980) Bureau of Labor Statistics (1980-1985)	1975-1.47 1976-1.57 1977-1.69 1978-1.81 1979-1.85 1980-1.99 1985-2.40
Forecast Time Period	EPA	1/1/76-12/31/85
Unemployment Rate in 1985 (Full Employment Economy)	Bureau of Labor Statistics	4.0 to 4.5%
Federal Expenditures in 1980 and 1985 Excluding Transfers and Pollution Control Programs (Millions 1975 Dollars)	Department of Commerce, Bureau of Economic Analysis	1980-156,400 1985-173,400
Federal Expenditures for Pollution Control	EPA	

The GNP and unemployment rate estimates selected for the Reference Scenario are intended to represent the current best estimates of what can be achieved nationally between 1975 and 1985, through a combination of public sector monetary and fiscal policies. The Reference Scenario target objectives for the GNP and its components for 1975 through 1985 represent a combination of the Council of Economic Advisors (CEA) and U.S. Office of Management and Budget (OMB) forecasts for the period of 1975 through 1980, and the Bureau of Labor Statistics (BLS) projected economic growth for the 1981-1985 period, as contained in The Structure of the U.S. Economy in 1980 and 1985 (U.S. Department of Labor, Bureau of Labor Statistics, Bulletin 1831, op.cit.). Assumptions about labor force and labor productivity used are those contained in the BLS projections with the greatest long-run likelihood based upon GNP supply-oriented (or potential-GNP) concepts. These projections are used since they are tempered by personal income, demand, and demographic change considerations.

A steadily declining unemployment rate through the forecast period is required to be consistent with both the GNP forecasts and assumptions about labor force and productivity for the Reference Scenario. The unemployment rate thus declines monotonically over the period from the high rates of the mid-1970's to a rate between 4.0 and 4.5 percent in the mid-1980's. The annual changes in productivity presented in the Reference Scenario are those assumed in the BLS projections (Structure of the U.S. Economy in 1980 and 1985, op.cit., Chapters 1 and 2 and Appendix A). These assumptions concerning GNP, the labor force, and labor productivity replace, for the Reference Scenario, those originally used in the INFORUM projections (Almon, et al., 1985: Interindustry Forecasts of the American Economy, op.cit., Chapter 1).

The Reference Scenario assumptions also include the setting of Federal expenditures for non-pollution-control activities in 1975 dollars (excluding transfers) at $156,400 million in 1980 ($106,060 million and $50,340 million, defense and non-defense, respectively) and $173,400 million in 1985 ($115,200 million and $58,200 million, defense and non-defense, respectively), with interpolation used to generate forecasts for intervening years. In addition, personal disposable income per capita is adjusted to produce, using INFORUM, the desired GNP and unemployment targets specified above.

The Reference Scenario represents a calibration of the SEAS system to the assumed GNP projections and unemployment rates in the absence of pollution control expenditures induced by Federal legislation. This does not mean that there are no pollution control expenditures implied in the Reference Scenario because there are substantial levels of such investments which would have been incurred even in the absence of federally legislated abatement policies. The levels for these expenditures were taken from forecasts developed by EPA.

The Reference Scenario is intended to reflect neither an unusually high energy consumption rate nor an unrealistic energy conservation effort. The energy consumption assumptions contained in the Federal Energy Administration's Project Independence report for the "Business as Usual" case, with oil at $7 per barrel, were thus used in the Scenario. The assumptions are summarized in Table B-2 in terms of the projected total gross consumption of energy resources in trillions of Btu's by fuel source.

Table B-2.
United States Total Gross
Consumption of Energy Resources
(Business-as-Usual Without Conservation - $7/Bbl Oil)[1]

Fuel	1972	1977	1980	1985
Coal	12,495	16,854	18,074	19,888
Petroleum	32,966	37,813	41,595	47,918
Natural Gas	23,125	21,558	22,934	23,947
Nuclear Power	576	2,830	4,842	12,509
Other	2,946	3,543	4,014	4,797
Totals	72,108	82,598	91,459	109,059

Source: Project Independence Report, Federal Energy Administration, Appendix A1, p.37, November 1974.

[1] Data shown is in trillions of Btu's.

REFERENCE ABATEMENT SCENARIO

The Reference Abatement Scenario differs from the Reference Scenario in that it includes among its assumptions the incremental pollution control practices, along with their attendant employment, costs, and effects on residuals, necessary to achieve compliance with Federal legislation. (Municipal costs are based on available Federal subsidy funds rather than compliance regulations for purposes of this report.) Most of the unit cost data used for calculation of these costs in SEAS was provided in constant 1973 dollars. Since the INFORUM data is currently expressed in constant 1971 dollars, it was necessary to first deflate the abatement cost input values from 1973 to 1971 dollars, and then to inflate the computed results back to 1975 dollars for presentation in this report. The deflation and inflation factors used for these purposes are presented in Table B-3.

Abatement costs are computed and analyzed in terms of annual investment, annual O&M costs, annualized capital costs, capital-in-place, and number of employees directly engaged in pollution control activities. Total annual costs are computed as the sum of annual O&M costs and annualized capital costs. The annualized capital costs are derived by applying to the annual investment amounts a capital recovery factor of:

$$\frac{i(1+i)^N}{(1+i)^N - 1}$$

where "i" is the annual interest rate expressed as a fraction and "N" is the life of the abatement equipment in years. For these calculations, a nominal interest rate of 10 percent is assumed for both the private and public sectors and abatement equipment life varies with the type of control technology being applied.

Table B-3
Summary of Inflation and Deflation Factors[1]

Type of Abatement Cost	Sources	Capital[2] 1973-71	Capital[2] 1971-75	O&M[2] 1973-71	O&M[2] 1971-75
Water	Engineering News Record	0.879	1.330	0.898	1.295
Air-Electrostatic Precipitator	Joy Manufacturing Co., Nelson Electricity Cost Index	0.708	2.136	0.909	1.718
Air-Building Evacuation	Chemical Engineering Plant Cost Index, Nelson Electricity Cost Index	0.943	1.541	0.909	1.718
Air-Fuel Switching, Afterburners, Incinerators	Chemical Engineering Plant Cost Index, Nelson Fuel Cost Index	0.943	1.541	0.892	2.138
Air-All Other Equipment	Chemical Engineering Plant Cost Index, Nelson Operating Cost Index	0.943	1.541	0.939	1.533

[1] A General GNP Inflation Rate of 1.311 was used to convert GNP estimates from 1971 to 1975 dollars (Source: Bureau of Labor Statistics)

[2] Deflation factors are for 1973 to 1971 dollars and inflation factors are for 1971 to 1975 dollars.

Federal expenditures and non-defense Federal employment are both incremented in the Reference Abatement Scenario to account for Federally funded pollution control programs and activities. These increments, which are added to the corresponding values from the Reference Scenario, are presented in Table B-4.

Table B-4.
Federal Expenditure and Employment Increments for the Reference Abatement Scenario

	1985
Federal Expenditure Increment	
Non-Defense (Millions of 1975 Dollars)	+2,564
Defense (Millions of 1975 Dollars)	+384
Federal Employment Increment (Millions of People)	+0.2

Unemployment rates were calibrated in the Reference Scenario to near full-employment levels of 4.0 to 4.5 percent during the 1980's. The addition of pollution control investment capital, employment, and Federal expenditures tends to drive unemployment below these levels. When this occurs, the per capita disposable income is constrained in the Reference Abatement Scenario to reflect a typical inflation dampening fiscal policy. The scenario is then run again until unemployment is equal to or greater than 4.0 percent.

The Reference Abatement Scenario assumes that all sources of pollution will fully comply with the EPA and state regulations and guidelines developed in response to the Clean Air Act of 1970 and the 1972 Amendments to the Federal Water Pollution Control Act. Detailed assumptions concerning such compliance may be found in Section Two (Air) and Section Three (Water) of this report.

LOW PRODUCTIVITY SCENARIOS

The Low Productivity and Low Productivity Abatement Scenarios differ from their Reference Case counterparts in that they make use of the productivity functions and growth assumptions contained in the INFORUM model as obtained from the University of Maryland. Compared with the Reference Scenarios, this reflects a slowing down of productivity because of shifts toward service industries in the pattern of final demand, and because of a lessening of the rate of productivity increase in other industries. GNP estimates for the Low Productivity Scenario which correspond to these assumptions are shown in Table B-5 and are compared with those for the Reference Scenario.

Table B-5.
Comparison of GNP Estimates for the
Low Productivity and Reference Scenarios
(In Trillions of 1975 Dollars)

	Low Productivity GNP	Reference Case GNP
1975	1.53	1.47
1977	1.67	1.67
1980	1.84	2.01
1983	1.99	2.22
1985	2.09	2.36

ENERGY CONSERVATION SCENARIO

The two Energy Conservation scenarios approximate energy usage forecasts contained in the Federal Energy Administration's "Business-as-Usual With Conservation" scenario where the import price of oil is $11 per barrel. (See Appendix A1, page 46 of the November 1974 Project Independence Report.) The energy consumption estimates in the Energy and Energy Abatement Scenarios each reflect a net reduction of approximately 13 quadrillion Btu's compared with their corresponding Reference Case scenarios. The following types of changes were introduced to achieve these energy savings:

1. A reduction in the household consumption of fossil fuels for air conditioning and heating to simulate raising the thermostat setting in the summer and lowering it in the winter.

2. A reduction in personal consumption expenditures for gasoline to simulate increased carpooling (with an

automobile occupancy ratio of 1.96 persons per vehicle as compared to the Reference Case occupancy ratio of 1.56). Increased shifts to mass transit are also included for the Energy Case scenarios, such as the modal split comparison between the Reference and Energy Scenarios for 1985 shown below:

Intracity	Reference	Energy
Auto	0.9070	0.8690
Bus	0.0230	0.0610
Rapid	0.0350	0.0350
Rail	0.0350	0.0350

Intercity	Reference	Energy
Auto	0.8650	0.8250
Air	0.0950	0.0950
Bus	0.0300	0.0500
Rail	0.0100	0.0300

3. A reduction in the interindustry fossil fuel use coefficients for energy-intensive inputs by substitution of less energy-intensive industries. These measures include: shifts to returnable beverage containers, reductions in the use of artificial fertilizers, reduced use of packaging materials, and some recycling of energy-intensive materials.

4. Miscellaneous changes to reflect improved energy housekeeping activities by various industries.

Appendix C.
Impact of Increased Federal Grants for Municipal Wastewater Treatment

A companion scenario to the Reference Abatement Scenario was constructed which continued the Federal grant program for municipal wastewater treatment plants through 1977-85. The comparative Federal outlay data for this scenario and the Reference Abatement Scenario is provided in Table 3-14 of Section Three. This scenario is identified as the Municipal Scenario (or Scenario 2A).

Table C-1 provides a summary of relative macroeconomic impacts of the Municipal Scenario as compared to the Reference Abatement Scenario; the primary statistics show only small differences between the two scenarios. The additional funds injected into an economy operating at full-supply-GNP require that the disposable income per capita be reduced from 1980 to 1985 on the order of 0.34 percent, which reduces personal consumption expenditures on the order of 0.31 percent. The major large changes occur where expected, in state and local health and welfare expenditures growing by 12.00 percent in 1985 and stimulating public construction by 10.54 percent in 1985. Net water residuals, except for dissolved solids, decline by over 30 percent by 1980, with a continuing increase in the efficiency treatment of suspended solids and nutrients over the decade. This reflects the continuing upgrading of municipal wastewater treatment plants.

Table C-1.
Comparison of the Macro-Statistics of the Municipal Scenario (SA) and the Reference Abatement Scenario (S2)
[(S2A-S2)/S2 in %]

Statistic	1977	1980	1983	1985
Gross National Product	0.03	0.11	0.25	0.09
Disposable Income Per Capita	0.00	-0.51	-0.56	-0.34
Federal Expenditures	0.00	0.00	0.00	0.00
Personal Consumption Expenditures	0.00	-0.36	-0.44	-0.31
Total Output	0.03	0.14	0.28	0.08
Investment	0.02	0.11	0.25	-0.03
State & Local Health & Welfare	0.10	3.19	9.43	12.00
Public Construction	0.69	13.54	20.14	10.54
Net Water Residuals				
Biochemical Oxygen Demand	-30.63	-31.48	-32.72	-31.21
Suspended Solids	-14.59	-22.59	-33.64	-42.99
Dissolved Solids	0.02	0.01	0.15	0.15
Nutrients	-14.98	-32.16	-51.10	-64.71
Water Municipal Costs				
Annualized Costs				
Capital	1.93	30.31	94.49	124.19
O&M	1.50	31.96	95.71	125.45
Capital in Place	1.93	30.31	94.49	124.19
Direct Employment	1.48	31.96	95.70	125.47

Appendix D.
Estimating the Cost For
Industries to Control
Pollution

COST ESTIMATION METHODOLOGY

Industrial facilities are required to control their air pollution emissions if they are so regulated by a State Implementation Plan (SIP) or by Federal New Source Performance Standards (NSPS). Under the SIP program, states are obliged by the Clean Air Act to specify the emission controls required by each industrial sector to achieve the Federal ambient air quality standards throughout the state. Thus, significant interregional differences in treatment may exist due to existing ambient air quality at the time regulations are implemented in each state. For new plants, interregional treatment is more nearly identical because Federal Air NSPS's apply to plants built or extensively modified after the particular NSPS guideline for that industry is promulgated. As of August 1975, NSPS's had been published for 17 industries. The NSPS allowable emission levels are usually more stringent than those for existing sources; hence, quite often unit control costs for plants regulated by NSPS are greater than for plants regulated by SIP's.

The deadline for meeting the Federal ambient air quality standards was July 1, 1975. Industries have not yet made the expenditures necessary to achieve their part of the emissions reduction required to meet ambient standards. Industries are continuing to install air pollution abating equipment, however, and for the purposes of this report, it was assumed that the required air abating investment needed by 1978 will be made by the end of 1978, when the final series of standards is to be met. It is also assumed that BPT standards for water pollution control will be met in 1977, and that BAT standards compliance will be achieved in 1983.

Seventy-two industrial sectors have significant control costs for either or both air and water pollution control. The number of sectors within each aggregate industry classification is shown in Table D-1.

Table D-1.
Distribution of Industrial Cost-Control Sectors

Aggregate Industry	Total Industrial Sectors	Air Cost Sectors	Water Cost Sectors
Agriculture	1	0	1
Mining	3	3	0
Food Processing	9	1	8
Textiles	2	0	2
Paper & Lumber	6	2	5
Chemicals	12	6	6
Petroleum	3	3	1
Rubber	1	0	1
Ferrous Metals	4	4	2
Nonferrous Metals	9	8	7
Stone, Clay, Glass	8	5	5
Machinery & Equipment	5	1	4
Electric Utilities	1	1	1
Trade & Services	2	2	0
Miscellaneous	6	5	1
Total	72	41	44

But this listing does not provide a good appreciation for the detail at which the abatement cost estimates are made. For example, the steel-making industry, for purposes of air pollution control, is a single item under Ferrous Metals in the above table. However, 22 different industrial segments are actually defined, each with its own cost curve for capital expenditure and O&M as a function of plant size. There are 497 industrial segments within the 72 industrial cost-control sectors for which air or water control costs are estimated.

INDUSTRIAL SEGMENTS:
MODEL PLANTS, UNIT COSTS AND GROWTH

In order to calculate pollution control costs, industries are represented by "segments" and "model plants". A "segment" is all or a portion of an industry that has: (1) the same production process, (2) the same pollution control technology, and (3) the same pollution control standards. For example, the Kraft Paper Industry is dealt with for purposes of air pollution control costs in terms of 10 different segments. These segments are shown in Table D-2. "Model plants" are the building blocks of a segment; that is, a segment's capacity for production is comprised of capacity within a number of model plant size groupings that are classified as either "existing" or "new" (new facilities are those constructed after the date when the Clean Air Act or Clean Water Act first affects that industry). For example, Segment 7 for Kraft Paper (Smelting Tanks) has three model plant sizes (454, 907, and 1,361 units of production per day). There are existing facilities in all three size groupings, but, during the 1976-85 period, new facilities are expected to be built in only the middle-size class.

Table D-2.
Kraft Paper Industry Segment Definitions

Process	Control Technology	Pollution Standard
1. Power Boiler	Electrostatic Precipitators	Federal Particulates
2. Boiler	Double Alkali Scrubber	Federal Sulfur Dioxide
3. Recovery Furnace	Electrostatic Precipitators	Washington/Oregon Particulates
4. Recovery Furnace	Venturi Scrubber	Washington/Oregon Particulates
5. Recovery Furnace	Recovery Furnace Replacement	Washington/Oregon Total Reduced Sulfur
6. Recovery Furnace	Black Liquor Oxidation	Washington/Oregon Total Reduced Sulfur
7. Smelting Tank	Orifice Scrubber	Washington/Oregon Particulates
8. Lime Kiln	Venturi Scrubber	Washington/Oregon Particulates
9. Stock Washer	Incinerate in Recovery Furnace	Washington/Oregon Total Reduced Sulfur
10. Evaporator	Incinerate in Lime Kiln	Washington/Oregon Total Reduced Sulfur

The cost of controlling air pollution from industrial sources is estimated for model plants. All existing capacity is expressed in terms of the model plants, and all new growth in capacity is also expressed in terms of these model plants. For example, existing plants which are classified into the smallest model plant (size grouping) in Segment 7 for Kraft Paper (454 units of production per day) are assumed to spend, on the average, as much for capital equipment to control each residual as the 454-unit model plant.

To calculate industrial costs of pollution control, each segment has a capital cost equation and an O&M cost equation that states dollar costs as a function of plant capacity or water use, based on the model plants. The air cost equations are derived from individual studies funded by EPA (see Section Two) and the water costs are obtained from the EPA Development Documents (see Section Three).

Each industrial segment is associated with one of the 185 industrial aggregate sectors of the INFORUM economic model via a side equation. These sectors and corresponding detailed subsectors of SEAS are shown in Tables D-3 and D-4, respectively. Due to this association, the growth of capacity or water use (and the accompanying growth in abatement costs) in each segment is dependent upon the dynamics of the interindustry model. Thus, if a user decreases the personal consumption purchases of automobiles, then the direct and indirect effects of this reduction in car sales will ripple throughout the system. The abatement costs for steel industries, aluminum industries and other industries indirectly impacted by the change in car sales will be calculated. In the same manner, additional purchases by a sector required for pollution control can be imposed and the specific direct and indirect impacts determined.

Table D-3.
The 185 Sectors of INFORUM

SECTOR NAMES

1	DAIRY FARM PRODUCTS	2	POULTRY AND EGGS	3	MEAT ANIMALS, OTH LIVESTK
4	COTTON	5	GRAINS	6	TOBACCO
7	FRUIT, VEGETABLES, OTH CROPS	8	FORESTRY AND FISHERY PROD.	9	NO DEF'N
10	AGR, FORESTRY + FISH SERVICE	11	IRON ORES	12	COPPER ORE
13	OTHER NON-FERROUS ORES	14	COAL MINING	15	CRUDE PETROLEUM, NAT. GAS
16	STONE AND CLAY MINING	17	CHEMICAL FERTILIZER MINING	18	NEW CONSTRUCTION
19	MAINTENANCE CONSTRUCTION	20	COMPLETE GUIDED MISSILES	21	AMMUNITION
22	OTHER ORDNANCE	23	MEAT PRODUCTS	24	DAIRY PRODUCTS
25	CANNED AND FROZEN FOODS	26	GRAIN MILL PRODUCTS	27	BAKERY PRODUCTS
28	SUGAR	29	CONFECTIONERY PRODUCTS	30	ALCOHOLIC BEVERAGES
31	SOFT DRINKS AND FLAVORINGS	32	FATS AND OILS	33	MISC FOOD PRODUCTS
34	TOBACCO PRODUCTS	35	BROAD AND NARROW FABRICS	36	FLOOR COVERINGS
37	MISC TEXTILES	38	KNITTING	39	APPAREL
40	HOUSEHOLD TEXTILES	41	LUMBER AND WOOD PRODUCTS	42	VENEER AND PLYWOOD
43	MILLWORK AND WOOD PRODUCTS	44	WOODEN CONTAINERS	45	HOUSEHOLD FURNITURE
46	OTHER FURNITURE	47	PULP MILLS	48	PAPER AND PAPERBOARD MILLS
49	PAPER PRODUCTS, NEC	50	WALL AND BUILDING PAPER	51	PAPERBOARD CONTAINERS
52	NEWSPAPERS	53	PERIODICALS	54	BOOKS
55	INDUSTRIAL CHEMICALS	56	BUSINESS FORMS, BLANK BOOKS	57	COMMERCIAL PRINTING
58	OTHER PRINTING, PUBLISHING	59	FERTILIZERS	60	PESTICIDES + AGRIC. CHEM.
61	MISC CHEMICAL PRODUCTS	62	PLASTIC MATERIALS AND RESINS	63	SYNTHETIC RUBBER
64	CELLULOSIC FIBERS	65	NON-CELLULOSIC FIBERS	66	DRUGS
67	CLEANING AND TOILET PROD.	68	PAINTS	69	PETROLEUM REFINING
70	FUEL OIL	71	PAVING AND ASPHALT	72	TIRES AND INNER TUBES
73	RUBBER PRODUCTS	74	MISC PLASTIC PRODUCTS	75	LEATHER + IND LTHR PROD
76	FOOTWEAR(EXC. RUBBER)	77	OTHER LEATHER PRODUCTS	78	GLASS
79	STRUCTURAL CLAY PRODUCTS	80	POTTERY	81	CEMENT, CONCRETE, GYPSUM
82	OTHER STONE + CLAY PRODUCTS	83	STEEL	84	COPPER
85	LEAD	86	ZINC	87	ALUMINUM
88	OTH PRIM NON-FER METALS	89	OTH NON-FER ROLL + DRAW	90	NON-FERROUS WIRE DRAWING
91	NON-FER CASTING AND FORGING	92	METAL CANS	93	METAL BARRELS AND DRUMS
94	PLUMBING AND HEATING EQUIP.	95	STRUCTURAL METAL PRODUCTS	96	SCREW MACHINE PRODUCTS
97	METAL STAMPINGS	98	CUTLERY, HAND TOOLS, HARDWR	99	MISC FABRICATED WIRE PRODUCT
100	PIPES, VALVES, FITTINGS	101	OTH FABRICATED METAL PRODUCT	102	ENGINES AND TURBINES
103	FARM MACHINERY	104	CONSTR, MINING, OIL FIELD MA	105	MATERIALS HANDLING MACH
106	MACHINE TOOLS, METAL CUTTING	107	MACHINE TOOLS, METAL FORMING	108	OTHER METAL WORKING MACHINER
109	SPECIAL INDUSTRIAL MACHINERY	110	PUMPS, COMPRESSORS, BLOWERS	111	BALL AND ROLLER BEARINGS
112	POWER TRANSMISSION EQUIPMENT	113	INDUSTRIAL PATTERNS	114	COMPUTERS AND RELATED MACHIN
115	OTHER OFFICE MACHINERY	116	SERVICE INDUSTRY MACHINERY	117	MACHINE SHOP PRODUCTS
118	ELECTRICAL MEASURING INSTRUM	119	TRANSFORMERS AND SWITCHGEAR	120	MOTORS AND GENERATORS
121	INDUSTRIAL CONTROLS	122	WELDING APP, GRAPHITE PROD	123	HOUSEHOLD APPLIANCES
124	ELEC LIGHTING AND WIRING EQU	125	RADIO AND TV RECEIVING	126	PHONOGRAPH RECORDS
127	COMMUNICATION EQUIPMENT	128	ELECTRONIC COMPONENTS	129	BATTERIES
130	ENGINE ELECTRICAL EQUIPMENT	131	X-RAY, ELEC EQUIP,NEC	132	TRUCK, BUS, TRAILER BODIES
133	MOTOR VEHICLES	134	AIRCRAFT	135	AIRCRAFT ENGINES
136	AIRCRAFT EQUIPMENT, NEC	137	SHIP AND BOAT BUILDING	138	RAILROAD EQUIPMENT
139	CYCLES, TRANS EQUIP,NEC	140	TRAILER COACHES	141	ENGR. + SCIENTIFIC INSTR.
142	MECH. MEASURING DEVICES	143	OPTICAL + OPHTHALMIC GOODS	144	MEDICAL AND SURGICAL INSTR.
145	PHOTOGRAPHIC EQUIPMENT	146	WATCHES AND CLOCKS	147	JEWELRY AND SILVERWARE
148	TOYS, SPORT, MUSICAL INSTR	149	OFFICE SUPPLIES	150	MISC MANUFACTURING, NEC
151	RAILROADS	152	BUSES AND LOCAL TRANSIT	153	TRUCKING
154	WATER TRANSPORTATION	155	AIRLINES	156	PIPELINES
157	FREIGHT FORWARDING	158	TELEPHONE AND TELEGRAPH	159	RADIO AND TV BROADCASTING
160	ELECTRIC UTILITIES	161	NATURAL GAS	162	WATER AND SEWER SERVICES
163	WHOLESALE TRADE	164	RETAIL TRADE	165	BANKS, CREDIT AGEN., BROKERS
166	INSURANCE	167	OWNER-OCCUPIED DWELLINGS	168	REAL ESTATE
169	HOTEL AND LODGING PLACES	170	PERSONAL AND REPAIR SERVICES	171	BUSINESS SERVICES
172	ADVERTISING	173	AUTO REPAIR	174	MOVIES AND AMUSEMENT
175	MEDICAL SERVICES	176	PRIVATE SCHOOLS AND NPO	177	POST OFFICE
178	FEDERAL GOV. ENTERPRISES	179	NO DEF'N	180	ST + LOC ELECTRIC UTILITIES
181	NON-COMPETITIVE IMPORTS	182	BUSINESS TRAVEL(DUMMY)	183	OFFICE SUPPLIES(DUMMY)
184	UNIMPORTANT INDUSTRY(DUMMY)	185	COMPUTER RENTALS(DUMMY)		

Table D-4.
The Subsectors of SEAS

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SUBSECTOR NAMES
 3  1  BEEF CATTLE FEEDLOTS             3  1  CORN                             3  2  SOYBEANS
 3  3  WHEAT                            7  1  APPLES                           7  2  POTATOES
 7  3  CITRUS                           9  1  MUNICIPAL SEWAGE                 9  2  WATER BASED PAINTS CONSUMPTN
 9  3  SOLVENT BASED PAINTS CONSUMP     9  4  TOTAL SOLID WASTE GENERATION     9  5  SEWAGE SLUDGE INCINERATION
 9  6  GASOLINE CONSUMPTION             9 30  MUNICP SEWAGE-PRIMARY TREAT      9 31  MUNICP SEWAGE-SECOND TREAT
 9 32  MUNICP SEWAGE-TERTIARY TREAT     9 33  MUNICIPL SEWAGE W/O TREATMNT     9 34  INCINERATION OF SOLID WASTE
 9 35  OPEN BURNING                     9 36  OPEN DUMPING & LANDFILL          9 37  MUNICIPAL INCINERATION
 9 38  ON-SITE INCINERATION             9 39  LANDFILL - FROM AIR CONTROLS     9 40  OTHER OPEN DUMP & LANDFILL
14  1  COAL/SYNTHETIC COAL FUELS       14 30  SURFACE COAL MINING             14 31  UNDERGROUND COAL MINING
14 32  SURFACE MINING-EASTERN          14 33  SURFACE MINING-WESTERN          14 34  COAL-SYNTHETIC FUELS
14 35  COAL                            14 36  COAL CLEANED & DRIED            14 37  COAL-NOT CLEAN/CLEAN-NOT DRY
14 38  COAL-SNG                        14 39  COAL-LOW BTU GAS                15  1  INDUST COMBUST OF NAT GAS
15  2  NATURAL GAS PROCESSING          15  3  CRUDE OIL DOMESTIC PRODUCT.     15  4  DOMESTIC NAT GAS PRODUCTION
15 30  SOUR NAT GAS PROCESS PLANTS     15 31  OTHER NAT GAS PROCESS PLANTS    16  1  ASBESTOS MINING
17  1  PHOSPHATE ROCK                  23  1  RED MEAT PROC-SLAUGHTERHOUSE    23  2  RED MEAT PROC-PACKINGHOUSES
23  3  RED MEAT PROC-PROCESSORS        23  4  POULTRY PROCESSING              23 30  SIMPLE SLAUGHTERHOUSES
23 31  COMPLEX SLAUGHTERHOUSES         23 32  LOW PROCESSING PACKINGHOUSES    23 33  HIGH PROCESSING PACKINGHOUSE
24  1  FLUID MILK,COTTAGE CHEESE       24  2  BUTTER                          24  3  NATURAL, PROCESSED CHEESE
24  4  ICE CREAM & FROZEN DESSERTS     25  1  CANNED & FROZEN SEAFOOD         25  2  CANNED,FROZEN FRUIT,VEGS,NEC
25  3  POTATOES                        25  4  CORN                            25  5  TOMATOES
25  6  APPLES                          25  7  CITRUS                          26  1  INDUST COMBUST OF COAL
26  2  INDUST COMBUST OF OIL           26  3  INDUST COMBUST OF NAT GAS       26  4  CORN MILLING
26  5  WHEAT,STARCH & GLUTEN           26  6  CEREALS                         26 30  CORN WET MILLING
26 31  CORN DRY MILLING                28  1  CANE SUGAR                      28  2  BEET SUGAR
28 30  CANE SUGAR - CRYSTALLINE        28 31  CANE SUGAR - LIQUID             35  1  INDUST COMBUST OF COAL
35  2  INDUST COMBUST OF OIL           35  3  INDUST COMBUST OF NAT GAS       35  4  WOVEN DRY PROC(GREIGE) MILLS
35  5  WOVEN FABRIC FINISHING MILLS    35  6  RAW STOCK, TOP, YARN DYEING     35 30  WOVEN FABR FINISH-COTTON,SYN
35 31  WOVEN FABR FINISH-SYNTHETICS    35 32  WOVEN FABR FINISH-WOOL          35 33  RAW STOCK,TOP,YARN DYE-WOOL
35 34  RAW STK,TOP,YARN DYE-COTTON     36  1  ADHESIVE PPL DRY PROC MILLS     36  2  PIECE DYEING,CARPET PRINTING
37  1  WOOL SCOURING                   38  1  KNIT FABRIC FINISHING           38 30  KNIT FABR FINISH-COTTON,SYN
38 31  KNIT FABR FINISH-SYNTHETICS     38 32  KNIT FABR FINISH-WOOL           41  1  TIMBER PRODUCTS PROCESSING
47  1  INDUST COMBUST OF COAL          47  2  INDUST COMBUST OF OIL           47  3  INDUST COMBUST OF NAT GAS
47  4  KRAFT - PULP                    47  5  SULFITE - PULP                  47  6  NSSC - PULP
47  7  GROUNDWOOD - PULP               47  8  PULP FROM WASTE PAPER           47  9  PULP - OTHER
47 30  KRAFT - BLEACHED                47 31  KRAFT - UNBLEACHED              47 32  NSSC - SODIUM
47 33  NSSC - AMMONIA                  47 34  NSSC - CROSS RECOVERY           47 35  OTHER WASTE PAPER
47 36  DEINKING                        47 37  PAPER BOARD FROM WASTE PAPER    47 71  KRAFT - RF (ESP)
47 72  KRAFT - RF(VENT,SCRUBBER)       50  1  BUILDING PAPER                  55  1  INDUST COMBUST OF COAL
55  2  INDUST COMBUST OF OIL           55  3  INDUST COMBUST OF NAT GAS       55  4  ACETALDEHYDE
55  5  ACRYLONITRILE                   55  6  ADIPONITRILE                    55  7  CITRIC ACID
55  8  DIMETHYL TEREPHTHALATE          55  9  DYES & DYE INTERMEDIATES        55 10  MALEIC ANHYDRIDE
55 11  PENTAERYTHRITOL                 55 12  PHENOL & ACETONE                55 13  PLASTICIZERS
55 14  PROPYLENE OXIDE                 55 15  TETRAETHYL LEAD                 55 16  FORMALDEHYDE
55 17  ETHYLENE OXIDE                  55 18  ETHYLENE DICHLORIDE             55 19  PHTHALIC ANHYDRIDE
55 20  CHLORINE                        55 21  NITRIC ACID                     55 22  HYDROFLUORIC ACID
55 23  SULFURIC ACID                   55 24  PHOSPHORIC ACID                 55 25  SODIUM CARBONATE
55 26  TITANIUM DIOXIDE                55 27  PHOSPHORUS                      55 28  DEFLUORINATED PHOSPHATE ROCK
55 30  ACET-HYDROG OF METHANOL         55 31  ACET-OXID ETHYLENE W/OXYGEN     55 32  ACET-OXID ETHYLENE W/AIR
55 33  FORMALDEHYDE-SILVER PROCESS     55 34  FORMALDEHYD-METAL OXIDE PROC    55 35  CHLORINE-DIAPHRAGM CELL
55 36  CHLORINE-MERCURY CELL           55 37  SODIUM CARBONATE-TRONA PROC     55 38  SODIUM CARBONATE-SOLVAY PROC
55 39  CHLOR EXTR-TITAN DIOX-ILMEN     55 40  CHLOR EXTR-TITAN DIOX-RUTILE    55 41  SULFAT EXTR-TITAN DIOX-ILMEN
55 71  SULFURIC ACID-SULFUR BURNING    55 72  SULFURIC ACID - WET GAS         59  1  PHOSPHATE FERTILIZER
59  2  NITRATE FERTILIZER              59 30  PHOSPHATE GRANULATION PLANTS    59 31  PHOSPHATE PRODUCTION PLANTS
59 32  TRIPLE SUPERPHOSPHATE           59 33  DIAMMONIUM PHOSPHATE            59 34  NORMAL SUPERPHOSPHATE
61  1  INDUST COMBUST OF COAL          61  2  INDUST COMBUST OF OIL           61  3  INDUST COMBUST OF NAT GAS
61  4  CARBON BLACK .                  61  5  ALUMINUM SULFATE                61  6  CALCIUM CHLORIDE
61  7  HYDROCHLORIC ACID               61  8  HYDROGEN PEROXIDE               61  9  POTASSIUM DICHROMATE
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Table D-4. (Continued)
The Subsectors of SEAS

61	10	POTASSIUM SULFATE	61	11	SODIUM CHLORIDE	61	12	SODIUM DICHROMATE
61	13	SODIUM METAL	61	14	SODIUM SILICATE	61	15	SODIUM SULFATE
61	16	ETHYLENE/PROPYLENE	61	17	BTX AROMATICS	61	18	ISOPROPANOL
61	19	ACRYLATES	61	20	AMMONIA	61	21	METHANOL
61	22	BENZENE	61	23	ETHYLENE	61	24	PROPYLENE
61	30	BTX-HYDRO TREAT, PYROLYSIS	61	31	BTX-SOLV EXTR FROM REFORMATE	62	1	POLYVINYL CHLORIDE
62	2	PHENOLIC RESINS	62	3	NYLON	62	4	POLYSTYRENE
62	5	LOW DENSITY POLYETHYLENE	62	6	HIGH DENSITY POLYETHYLENE	62	7	POLYPROPYLENE
63	1	SYNTHETIC RUBBER	64	1	RAYON	65	1	INDUST COMBUST OF COAL
65	2	INDUST COMBUST OF OIL	65	3	INDUST COMBUST OF NAT GAS	65	4	POLYESTER FIBERS
67	1	SOAPS AND DETERGENTS	68	1	SALE TRADE PAINTS	68	2	INDUSTRIAL PAINTS,N.E.C.
68	30	H2O SOLUBLE PAINT TRADE SALE	68	31	SOLVENT BASE PAINT TRADESALE	68	32	H2O SOLUBLE PAINT INDUSTRIAL
68	33	SOLVENT BASE PAINT INDUSTRIL	69	1	INDUST COMBUST OF COAL	69	2	INDUST COMBUST OF OIL
69	3	INDUST COMBUST OF NAT GAS	69	4	CRUDE OIL REFINING	69	5	JET FUEL PRODUCTION
69	6	GASOLINE PRODUCTION	69	30	REFINER W/CATALYTIC CRACKING	69	31	REFINER W/O CATALYTIC CRACK
69	32	TOPPING PLANTS	69	33	REFINERIES W/CRACKING	69	34	CRACKING(NO PETRO OR LUBES)
69	35	PETROCHEM(CRACKING,NO LUBES)	69	36	LUBE OIL(CRACK,NO PETROCHEM)	69	37	INTEGRAT(CRACK,LUBE,PETROCH)
71	1	ASPHALT	72	1	TIRES AND INNER TUBES	73	1	RUBBER RECLAIMING
73	2	LATEX MANUFACTURE	75	1	LEATHER TANNING	75	30	CHROME TANNING
75	31	OTHER TANNING	75	32	PULP HAIR/CHROME TANNING	75	33	SAVE HAIR/CHROME TANNING
75	34	HAIR REMOVED/CHROME TANNING	75	35	PULP,SAVE HAIR,CHROME,NO TAN	75	36	HAIR REMOVED/TANNED
75	37	SAVE HAIR/VEGETABLE	78	1	FIBERGLASS (INSULATION)	78	2	FLAT GLASS
78	3	PRESSED & BLOWN GLASS	78	4	GLASS CONTAINERS	78	30	PLATE GLASS
78	31	FLOAT GLASS	79	1	STRUCTURAL CLAY PRODUCTS	79	30	PERIODIC KILN W/FLASHING
79	31	OTHER STRUCTURAL CLAY KILNS	81	1	INDUST COMBUST OF COAL	81	2	INDUST COMBUST OF OIL
81	3	INDUST COMBUST OF NAT GAS	81	4	CEMENT	81	5	LIME
81	30	CEMENT - WET GRINDING	81	31	CEMENT - DRY GRINDING	82	1	ASBESTOS PRODUCTS
82	2	CRUSHED STONE	82	3	SAND AND GRAVEL	83	1	INDUST COMBUST OF COAL
83	2	INDUST COMBUST OF OIL	83	3	INDUST COMBUST OF NAT GAS	83	4	IRON FOUNDRY PRODUCTION
83	5	STEEL PRODUCTION	83	6	FERROALLOY PRODUCTION	83	7	COAL INTO COKING
83	8	STEEL FOUNDRIES	83	9	METAL/COIL SURFACE COATING	83	30	OPEN HEARTH FURN-INTEG. FAC.
83	31	BASIC OXY FURN-INTEGR. FACIL	83	32	ELECT ARC STEEL-INTEGR. FAC.	83	33	CUPOLA FURNACE
83	34	ELECT ARC-IRON FOUNDRY PROD	83	35	OTHER IRON FOUNDRY FURNACES	83	36	SUBMERGED ARC FURNACE
83	37	OTHER FERROALLOY FURNACES	83	38	BEEHIVE COKING	83	39	BYPRODUCT COKING
83	60	BASIC OXYGN FURNAC-NO GROWTH	83	61	BASIC OXYGN FURNAC-GROWTH	83	62	NO DEF'N
83	63	ELECT ARC FURNACE-NO GROWTH	83	64	ELECT ARC FURNACE-GROWTH	83	65	NO DEF'N
83	66	IRON FOUNDRY - CUPOLA	83	67	IRON FOUNDRY - ELECT ARC	83	68	FERROALLOY PROD.-FAB. FILTER
83	69	FERROALLOY PROD.-SCRUBBER	83	70	FERROALLOY PROD. - ESP	83	80	FINISHING OPERATIONS
83	81	BLAST FURNAC(PIG IRON PROD)	83	82	PELLETIZING	83	83	SINTERING
84	1	COPPER	84	30	PRIMARY COPPER	84	31	SECONDARY COPPER
84	32	COPPER SMELTING	84	33	HYDROMETALLURGY	84	34	SMELTING W/ROASTER
84	35	SMELTING W/O ROASTER	84	71	SEC BRASS & BRONZE-GROWTH	84	72	SEC BRASS & BRONZE-NO GROWTH
85	1	LEAD	85	30	PRIMARY LEAD	85	31	SECONDARY LEAD
86	1	ZINC	86	30	PRIMARY ZINC	86	31	SECONDARY ZINC
87	1	BAUXITE REFINING	87	2	ALUMINUM	87	30	PRIMARY ALUMINUM
87	31	SECONDARY ALUMINUM	87	32	HALL-HEROULT PROCESS	87	33	ALCOA PROCESS
87	34	PREBAKED ANODE	87	35	HORIZONTAL SODERBERG	87	36	VERTICAL SODERBERG
88	1	BERYLLIUM	88	2	MERCURY	88	3	URANIUM
88	4	MANGANESE	123	1	HOME APPLIANCES-SURFACE COAT	133	1	INDUST COMBUST OF COAL
133	2	INDUST COMBUST OF OIL	133	3	INDUST COMBUST OF NAT GAS	133	4	MOTOR VEH,PARTS-SURFACE COAT
160	1	ELECTRICITY BY COAL	160	2	ELECTRICITY BY OIL	160	3	ELECTRICITY BY GAS
160	4	ELECTRICITY BY NUCLEAR FUEL	160	5	ELECTRICITY BY HYDRO & OTHER	160	30	ELECT BY LOW SULFUR COAL
160	31	ELECT BY HIGH SULFUR COAL	160	32	ELECT-DISTILLAT,RESIDUAL OIL	160	33	ELECT BY HIGH SULFUR RES OIL
160	34	ELECT BY HTGR	160	35	ELECT BY LWR	160	36	ELECT BY GASIFIED COAL
160	37	ELECT BY NATURAL GAS	160	38	ELECT BY GEOTHERMAL,HYDRO	160	39	ELECT BY MUNICIPAL WASTE
162	1	SEWAGE SLUDGE INCINERATION	162	2	TOTAL SOLID WASTE GENERATION	162	30	INCINERATION OF SOLID WASTE
162	31	OPEN BURNING	162	32	OPEN DUMPING & LANDFILL	162	33	MUNICIPAL INCINERATION
162	34	ON-SITE INCINERATION	162	35	LANDFILL - FROM AIR CONTROLS	162	36	OTHER OPEN DUMP & LANDFILL
162	37	NO DEF'N	162	38	NO DEF'N	163	1	GRAIN HANDLING
163	30	GRAIN HAND-SMALL RURAL FACIL	163	31	GRAIN HAND-TERMINAL FACIL	163	32	GRAIN HAND-TERM FACIL(INLAND)
163	33	GRAIN HAND-TERM FACIL(PORT)	170	1	DRY CLEANING	170	30	DRY CLEAN-SYNTHETIC SOLVENTS
170	31	DRY CLEAN-PETROLEUM SOLVENTS	179	1	INDUST COMBUST OF COAL N.E.C	179	2	INDUST COMBUST OF OIL N.E.C.
179	3	INDUST COMBUST-NAT GAS N.E.C	179	4	RESIDENTIAL USE-NAT GAS	179	5	RESIDENT USE-DISTILLATE OIL
179	6	COMMERC/INSTITUT USE-NAT GAS	179	7	COMMERC/INSTITUT USE-OIL	179	8	COMMERC/INSTITUT USE-COAL
179	9	OTHER INDUSTRIAL USE	179	30	COMMERC/INSTITUT USE-RES OIL	179	31	COMMER/INSTITUT USE-DIST OIL